COMPARING AND EXPLORING NEW TEXT ENTRY AND EDIT METHODS FOR SMART TV

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Jingtian Li

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COMPARING AND EXPLORING NEW TEXT ENTRY AND EDIT METHODS FOR SMART TV

Approved by:

Dr. Young Mi Choi, Advisor
School of Industrial Design
Georgia Institute of Technology

Tim Purdy
School of Industrial Design
Georgia Institute of Technology

Wendell Wilson
School of Industrial Design
Georgia Institute of Technology

Date Approved: 5/5/2015

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ANOVA	Analysis of Variance
CPU	Central Processing Unit
SMS	Short Messaging Service
SUS	System Usability Scale
TV	Television
UI	User Interface

SUMMARY

Smart TVs are becoming an increasingly important multimedia device for home entertainment now. One of the most important interactions between users and a smart TV is typing and editing text. However, using current input methods to type and edit text on a smart TV is a challenge. This study discussed about current input methods for smart TVs and evaluated the effects of using smartphone touch gestures and virtual keyboards on typing and editing text for smart TVs.

This study presented a method to evaluate the effects of using smartphone touch gestures and virtual keyboard on the text entry and editing for smart TVs compared to current methods. A functional mobile input method for smart TVs was designed and developed for the user testing. User testing was conducted with 20 participants. The results clearly indicated that it was more efficient to use smartphone touch gestures and virtual keyboards as a text entry and edit method for smart TVs compared to the remote control and the touchpad. It also showed that the new method had similar user satisfaction as the physical keyboard, and it had much higher satisfaction than the remote control and the touchpad.

CHAPTER 1

INTRODUCTION

Smart TVs are becoming an increasingly important multimedia device for home entertainment now[1]. Generally, Smart TV is defined as a medium that provides TV broadcasting, Internet, applications, and intelligent services via the mounting of a CPU and an operating platform on the set-top box or display[1]. Smart TV has its own operating system, so it can provide not only TV channels but also different applications. Unlike traditional TVs, smart TV platforms provide more interaction and services, such as playing games, browsing websites, social networking, sharing images/videos and searching information[2]. One of the most important interaction between users and a Smart TV is typing and editing text[3]. This thesis discusses the current input methods for smart TVs, evaluates the effects of using smartphone touch gestures and virtual keyboard on the text entry and editing for smart TVs.

Problem Statement

The interaction and interface on a smart TV is very different from the traditional TV. The most common input device for a traditional TV is a standard remote control. With it, users can adjust volume, change channels or input simple numbers. Smart TV platforms are different in that text input is required to use many of the features. For example a user may need to input online account credentials, input key words to search for favorite TV shows, write comments in forums or app stores, or enter text in many other scenarios. Editing and correction of entered text in any of these cases is currently a challenge[4]. The experience of text entry and edit can affect users' experience when they are using their smart TVs.

Significance of the Problem

Currently we are in the midst of content revolution of the smart TV[5], and video contents are consumed from many different kinds of sources. When people want to watch videos, they might search online, buy a DVD, or watch live TV channels. Smart TV provides a universal platform on which people can access to different video contents via one smart TV or set-top box, so that people do not have to use different platforms or devices to watch the videos they like. People can also install many applications on smart TVs which provide new and diverse experiences[5]. However, the interaction between users and smart TVs is not satisfactory, especially bad input experiences such as typing, searching, and sending commands. This is one of the key reasons that the progress of the smart TV revolution has slowed down. [5]. As the core of input experience, text entry and editing has a significant effect on users' experience of using smart TVs, so the improvement of text entry and editing experience will speed up the development of the smart TV industry[5].

Goals of the Study

This study discusses the pros and cons of current input methods for smart TVs, such as traditional remote controls, touchpads, physical keyboards, and smart device virtual keyboards. Research needs to be performed keeping in mind the target users, on how different input method will impact the user experience of a smart TV. The purpose of this study is to evaluate the effects of using smartphone touch gestures and virtual keyboards on the text entry and editing for smart TVs. The critical parameters to be evaluated in the proposed research include: text input efficiency; text input satisfaction; text edit efficiency; and text edit satisfaction. This research might provide results that would provide evidence that using smartphone touch gestures and virtual keyboards can help to improve the text entry and editing experience for smart TVs.

CHAPTER 2

BACKGROUND

Introduction

Smart TV refers to a television set or set-top box with integrated Internet that provides TV broadcasting, Internet, applications, and intelligent services. The first smart TV patent could be tracked back to 1994, which described an intelligent TV system that could be linked to network data[2]. In addition, users could download different software onto this television platform based on their own needs. In late 2000s and early 2010s, digital TVs started to be accepted by the masses, and people started to have more needs on diverse interaction with their TVs and connecting their TVs to many other devices like flash drives, video game players, and computers[2]. The success of digital televisions improved the development and revolution of smart TVs during that period. In 2014, major TV brands had announced the production of smart TVs[2]. In the meantime, the interactions between users and TVs are changing continually. Unlike traditional TVs, users have more complex interactions with smart TVs. The key of the interaction is how users give input to the smart TVs, and the core of the input interaction is the text entry and editing[6]. This chapter examines the current state of art related to smart TVs, and also discusses current text entry and edit methods for smart TVs.

State of Art in Smart TV Platforms

This section examines the current state of smart TV platforms. The purpose of this prior art is to better understand the definition, category, and main features of smart TVs. Understanding different smart TV platforms and features is very important for the design of text entry and edit methods for smart TVs because different features decide how users interact with smart TVs and this interaction decides the design elements of input methods for smart TVs. This review includes commercial products related to smart TVs ranged from early 2000s to present day. Search engines used to discover current smart TV products include Google Patent, Google.com, Wikipedia.org and Amazon.com.

There are two categories of smart TVs in current market, one is a television set with a built-in CPU and has the capability of accessing to internet, and the other one is a set-top box for digital television that provides the ability of computing and internet access. Both smart TV platforms have their own operating systems, which allows users to download and install advanced applications or plugins. Smart TV platforms also provide multimedia contents such as TV channels, movies, music, photos, games, and even social networking from internet[2]. In addition, users can also get access to some user-generated contents through either external hard drives or cloud storage services. Main providers for smart TV sets include LG Smart TV, Samsung Smart TV, Sony TV, and Philips Net TV. Main smart TV set-top box platforms include Apple TV, Google Nexus Player, Google Chromecast, Amazon Fire TV, and Roku.

The main feature of all smart TV platforms is to provide online streaming contents with traditional television channels. Main streaming contents include Netflix, Amazon Instant Video, YouTube, Hulu Plus, HBO Go, WWE Network, PBS, Spotify, and Pandora. The streaming contents decide what users might input to smart TVs. The most common contents include the name of movies or shows and the name of actors. In addition, most online streaming services need users to log in before they can use the service. In this context, users need to input account information which contains email address and password. Another important feature of smart TVs is to provide different applications users can download. For example, LG Smart TV provides users the feature of downloading apps from online app stores[7]. These applications include news, streaming videos, online movies, stock information and instant weather information. In this context of searching app, users need to input the name of the app in the app store. There are also some other features on smart TV platforms, which provides new experience for users compared to traditional TVs. For example, many current smart TV service providers offer people ways to track or set reminders for shows, sports or important events[2]. In this context, users need to input the needed information to set a reminder on smart TVs.

Figure 1: LG Smart TV with different apps[8].

As mentioned above, there are two categories of smart TV platforms, built-in smart TVs and smart TV set-top boxes. Main TV manufacturers like Samsung and LG prefer to develop and manufacture smart TVs with integrated Internet hardware[9], while other middleware providers like Apple, Amazon, Google would prefer to design and develop smart TV set-top boxes. There are some differences on the features and services provided by different smart TV set-top platforms (Fig. 2). The advantage of the built-in smart TV sets is that users do not need to buy extra devices to connect to their TVs and they use only one universal remote control to interact with the TV. For smart TV set-top boxes, the advantage is that users can get hardware and software updates without changing their current televisions, and all they need is just to buy an up to date smart TV box. Some set-top box mainly relies on one multimedia resource, for example the main video resource for Apple TV is from iTunes[10]. Some set-top boxes contain many online contents or applications developed by third parties, such as Roku[11]. While other smart TV boxes have a combination of a video game console and a set-top box, like Amazon Fire TV and Google Nexus Player. Some are devices that can connect TVs to users' smart devices, such as Google Chromecast[12]. The development trend is that more and more set-top boxes provide more video resources, applications, and interaction between users' different smart devices[2]. With such large amount of contents, text entry and editing becomes a very important interaction between users and smart TVs because the fastest way for users to find information is typing key words onto smart TVs to search the content.

Comparision Items	Amazon Fire TV	Roku 3	Apple TV	Google Chromecast
Features				
XBMC	No	No	No	No
Social Media	No	No	No	No
Browser	No	No	No	No
USB Player	No	Yes	No	No
Micro SD Player	No	No	No	No
Video Chat	No	No	No	No
Voice Search	Yes	No	No	No
HDMI video out (up to 1080p)	Yes	Yes	Yes	Yes
Certified Dolby Digital Plus surround sound	Yes	No	No	No
Optical audio out	Yes	No	No	No
Processor	Quad-core	Dual-core	Single-core	Single-core
Memory	2 GB	512 MB	512 MB	512 MB
Ethernet (wired connectivity)	Yes	Yes	Yes	Yes
Wi-Fi	Dual-band/Dual-antenna (MIMO)	Dual-band/Dual-antenna (MIMO)	Dual-band/Dual-antenna	Single-band
Remote with no line of sight required	Yes	Yes	No	No
Popular Services				
TV channel content	n/a	n/a	n/a	n/a
Netflix	Yes	Yes	Yes	Yes
Amazon Instant Video	Yes	Yes	No	No
Hulu Plus	Yes	Yes	Yes	Yes
Crackle	Yes	Yes	Yes	Yes
YouTube	Yes	Yes	Yes	Yes
HBO GO	No	Yes	Yes	Yes
Showtime Anytime	Yes	Yes	No	No
WatchESPN	Yes	Yes	Yes	No
Bloomberg TV	Yes	No	Yes	No
Vevo	Yes	Yes	Yes	Yes
Pandora	Yes	Yes	No	Yes
Xfinity	No	n/a	n/a	n/a
Vudu	No	Yes	Yes	Yes

Figure 2: Comparison of different smart TV set-top boxes[8].

Smart TV User Interface

Different smart TV platforms were discussed in the above paragraphs. This section examines the current state of smart TV user interfaces on different platforms, and discusses the design trends of smart TV user interfaces. This review can be used as a reference for the interface design of text entry and edit methods. User interfaces from both built-in smart TVs and smart TV set-top boxes were reviewed.

One of the most popular UI design language for smart TVs is the flat design and the “Card” UI. One example is the user interface on LG smart TV, which runs the WebOS[13]. The system uses a “card” user interface to present users’ applications and manage multiple tasks. Users can use right and left flicking gestures to switch between different running applications on the UI. To close applications, users simply flick the app card up and off the screen[13]. The organization of the application cards can be customized by users’ preferences. To find media contents, users need to select the LG store icon from the Launcher. The user interface of LG app store is very simple and clear, but also provides enough details about the TV shows or movies listed. The latest LG smart TV is using the flat UI design language. There is another smart TV platform, Samsung Smart TV Tizen platform[14], using the card and flat UI design. There is a row of icon cards on the bottom of the screen. By clicking the icon card with a remote control, users can launch an application[15]. To go back to the home screen, users can click the Smart Hub button on the Samsung remote control.

(a) (b)

Figure 3: (a) LG Smart TV WebOS user interface; (b) Samsung Smart TV Tizen user interface.

All the smart TV user interfaces mentioned in the above paragraph are from built-in smart TV sets. However, another approach to learn more about smart TV user interfaces is to investigate the UI provided by smart TV set-top boxes. A good example is the user interface of Apple TV. The first and second generation of Apple TV used Front Row interface which was similar to the Front Row on the Mac[10]. This kind of UI allowed users to view contents by name or date. In 2008, Apple updated the user interface of Apple TV and they stopped the use of front row interface. Instead a new interface organized in six groups on the home screen was presented. Users can use the remote control to select different icons on the screen. The third generation of Apple TV used rounded rectangle icons which had the same visual style as iOS 6. The latest UI on Apple TV is Apple TV Software 7.2 which has the same design language as iOS 8[10].

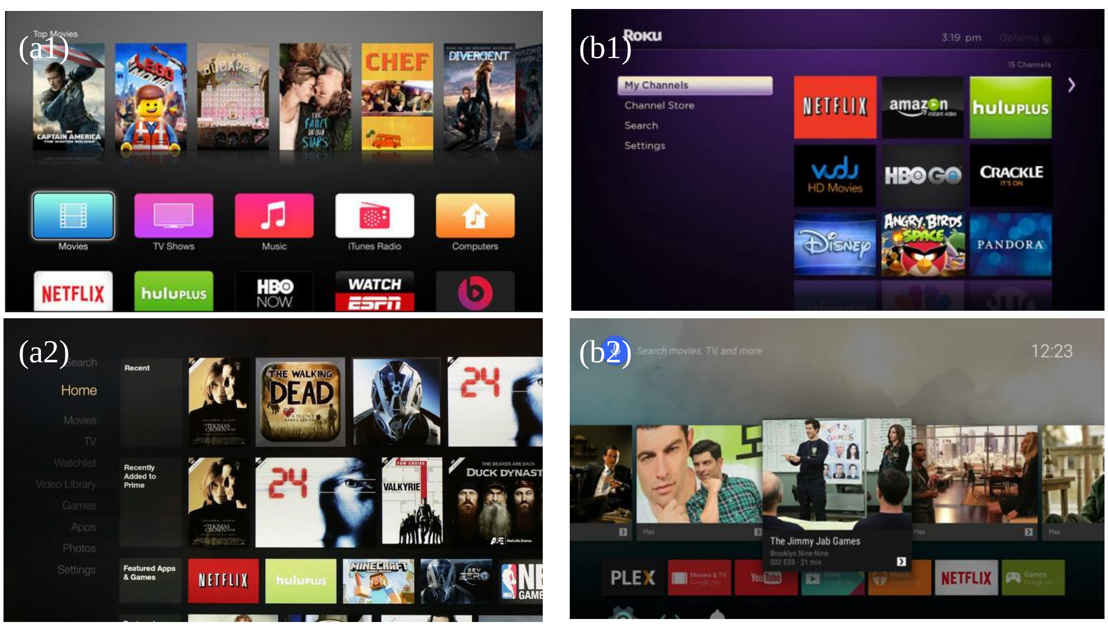


Figure 4: (a1) Apple TV user interface; (a2) Amazon Fire TV user interface;

(b1) Roku player user interface; (b2) Google Nexus Player user interface.

However, the layout of the new UI on Apple TV is the same as previous one. Another representative smart TV user interface is from Roku player. The home screen UI includes two parts, the left part is the main menu bar which users can select My Channels, Channel Store, Search, Settings from top to bottom, and the right part shows the contents in three columns based on the menu users selected. The user interface of Roku uses skeuomorphic design language instead of flat design. Another smart TV set-top box, Amazon Fire TV, also uses the same UI layout as Roku. However, Amazon Fire TV uses the flat design language for its user interface. Another example is Google Nexus Player, which runs Android operating system. The user interface of Nexus Player contains a search bar on the top and several rows of multimedia contents[15]. The user interface of Nexus Player follows the design guideline of Google material design language.

Interactive Technologies for Smart TVs

In the above paragraph, user interfaces were discussed from both built-in smart TV sets and smart TV set-top boxes. This section investigates current interactive technologies applied on different smart TV platforms and reviews how these technologies effect the interaction between users and different smart TV user interfaces.

Based on the review of current smart TV platforms, the most common interaction for users is the use of a remote control to send commands to smart TVs. Nearly all the smart TV devices come with a remote control. However, the remote control for built-in smart TVs is a little different from smart TV set-top boxes. For example, the remote control for LG smart TV has a "mouse wheel" on it so that users can scroll it to switch between different pages in few steps. In addition, this remote control also supports spatial gesture so that users can move the cursor on the screen by moving their hands. Another example of the remote control is designed for Samsung Smart TV ES8000 model. The most important feature of this remote control is the touchpad area. Users can use touch gestures to control the cursor on the screen. With the touch gesture, users can point to the icon easily and open an app quickly. As mentioned, remote controls for smart TV set-top boxes are different. One example is the remote control for Apple TV. Most of the time, users use the arrow (up, down, right, left) buttons to switch between different icons and use the center button to open an app. Similar to Apple TV, the remote control for

Amazon Fire TV provides the same interaction for users. In addition, there is a voice search button on it so that users can give audio input to their smart TVs. This feature provides an easy way for users to input text or send command to their TV. Users can speak the name of movies or shows to the remote control while they are pressing the voice search button, then the system will convert users' voice into text and appear on the screen. Much like the Amazon Fire TV, Google Nexus Player has the same remote control which support audio input[16]. Another new interactive technology for smart TVs is the connection and interaction between smart TVs and other smart devices such as smartphones, computers and tablets. For example, Apple Air play allows users to share multimedia contents between iPhone, iPad, Mac and Apple TV. Google Chromecast can mirror the video from users' mobile or web browser to TV. Google Nexus Player provides a mobile app which can be used as a traditional remote control for users.

Figure 5: (a) LG Smart TV remote control with a "mouse wheel"; (b) Samsung Smart TV remote control with a touchpad; (c) Apple TV remote control with arrow (up, down, left, right) buttons; (d) Google Nexus Player remote control with an audio input button.

From the discussion in above paragraphs, current main interactive technologies for smart TVs include the traditional remote control, spatial gesture, touchpad, speech recognition, and smart device control. These technologies decide the development status of current text entry and edit methods.

Text Entry and Edit Methods for Smart TVs

This section discusses current text entry and edit methods for smart TVs based on current smart TV interactive technologies and user interfaces as mentioned above.

This review begins with the most common text input method for smart TVs- the remote control input method[4]. This method is used on nearly all the smart TV platforms[17]. There are two methods using the remote control: one using the SMS style keypad and one using on-screen virtual keyboard[18]. The SMS style keypad was more used on traditional TV and earlier built-in smart TV sets, but currently most smart TVs, including LG smart TV, Apple TV, Amazon Fire TV, Roku Player, and Google Nexus Player, are using the on-screen keyboard as their main text entry methods. Users can use the arrow buttons on the remote control to select different characters from the on-screen virtual keyboard to input text on smart TVs. Another way of text entry and edit method is using spatial or touch gestures to select keys on the screen virtual keyboard. For example, the LG Smart TV remote control supports spatial gesture, so that users can move the screen cursor by moving the remote control to select characters on the screen[7]. Samsung Smart TV comes with the touchpad remote control so that users can move their fingers on the touchpad to interact with the on-screen keyboard to type and edit text. All these text entry and edit methods are designed and developed by the original smart TV manufacturers or set-top box providers. However, some third party companies have also designed some text entry and edit hardware and software for smart TVs. One example is the small version of a computer keyboard designed for smart TVs. Using this input method, users can type text by pressing the physical buttons on the keyboard, and when users need to edit text they can move the cursor by using arrow buttons on the physical keyboard[19].

Another new input method developed in recent years is using the smart device virtual keyboard to input text to smart TVs. Some smart TV set-top box providers designed a mobile application on smartphones and tablet platforms, which allows users to connect their smart devices to smart TVs and input text to smart TVs by using a virtual keyboard on smart devices. One example is the Amazon Fire TV mobile app which allows users to use the keyboard on smartphones to input text on TVs. However, this app did not provide an efficient way for users to edit text. Users need to delete all the text they typed and retype to edit by using this mobile app. As mentioned in previous review on smart TV interactive technologies, the speech recognition is new technology applied on smart TV platforms such as Amazon Fire TV and Google Nexus Player. Users can use the voice search button on the remote control to input text. This is a very efficient and intuitive text entry method. However it is very difficult to input long sentences and it is impossible to edit the text after inputting the text.

Figure 6: Graphics showing concepts of different text entry and edit methods for smart TVs. (a) Arrow buttons on remote control with an on-screen keyboard; (b) Touchpad on the remote control with an on-screen keyboard; (c) Physical keyboard; (d) Smart device virtual keyboard; (e) Audio input.

Based on the review above, current existing smart TV text entry and edit methods can be categorized into five basic methods as above Figure 6. Each input method has its own pros and cons. In previous research by Iatrino and Modeo [20], when typing text the use of physical remote keyboard is better appreciated compared to the use of arrow buttons on a remote control with an on-screen virtual keyboard. Traditional remote controls are not suitable to edit text on smart TVs. For example, Amazon Fire TV does not allow users to move the cursor on the text, and if users want to edit a typo in the sentence, they need to delete all the characters they typed up to the word they want to edit, and then retype. However, the interaction like touchpad is suitable to edit text, because users can move the cursor easily. In the research by Fong-Gong Wu, Yu-Chun Huang, and Meng-Long Wu, though the typing context in this research was not for smart TVs, however that research showed that current virtual keyboards on the smartphone was very flexible for users to switch between different keyboards (number, symbol)[21].

Pros	○ Cheap; ○ Fits almost all TVs.	○ Easy to edit text; ○ Move the cursor; ○ Possible to select text;	○ Type fast;	○ Input fast for short words;
Cons	○ Type slowly; ○ Hard to change case; ○ Hard to edit text; ○ Impossible to select text; ○ Hard to type long text.	○ Type slowly; ○ Hard to type long text.	○ Too many buttons on the remote control; ○ Impossible to switch different keyboards (number, symbol)	○ Impossible to edit text; ○ Impossible to type symbol; ○ Hard to type long text; ○ Impossible to change case.

Figure 7: Comparison of basic text entry and input methods for smart TVs.

CHAPTER 3

DESIGN AND DEVELOPMENT

Based on previous research and examining the background of smart TVs in the previous paragraphs, this chapter proposes a new text entry and edit method for smart TVs. The design requirement is to design and develop a new input method for smart TVs which will be more efficient in text entry, editing capabilities and provides a better user experience. The main features and functions of this new method were discussed in this chapter. A functional prototype was developed for later evaluation and user testing.

Concept

In the research by Diogo Pedrosa and Erick L. Melo[17], a method using a smart device virtual keyboard to input text onto smart TVs was proposed. As mentioned in above chapter, some smart TV set-top box providers designed some mobile application on smartphones which allowed users to connect their smart devices to smart TVs and input text to smart TVs by using the virtual keyboard on smart devices. The advantage of using a virtual keyboard on a smartphone is that users are familiar with using a smartphone keyboard and the keyboard is very flexible for users to switch between different keyboards (number, symbol). However, the biggest problem of the method of using virtual keyboards is that they do not provide an efficient interaction for users to edit text. This disadvantage would slow down users' typing and editing speed. Previous research also showed that the advantage of touchpad was that it performed well when editing text because users could easily move the cursor with their fingers. The concept of the new method this study proposed combined the typing advantage of the virtual keyboard and the editing advantage of the touchpad. The new method was a mobile app which had the functions of a touchpad and a smartphone virtual keyboard.

Features and Functions

The form of the new input method is a mobile app which allows users' smartphones to connect to smart TV set-top boxes via WiFi network. This feature supports the exchange of data between smartphones and smart TV set-top boxes. The UI style of the mobile app follows the smart TV design language as mention on Chapter 1. The core function of this app includes both text entry and editing on smart TVs. The user interface of the core functions is composed of two parts (Fig. 8(c)). One part is a virtual keyboard interface on the bottom of the screen which allows users to type on smart TVs. The other part is a blank touchpad area on the top. This part allows users to move the cursor in text field on smart TVs so that users can edit the text at any point in the text field. The rounded button in the touchpad area can be pressed to quickly move the cursor to the end of the sentence.

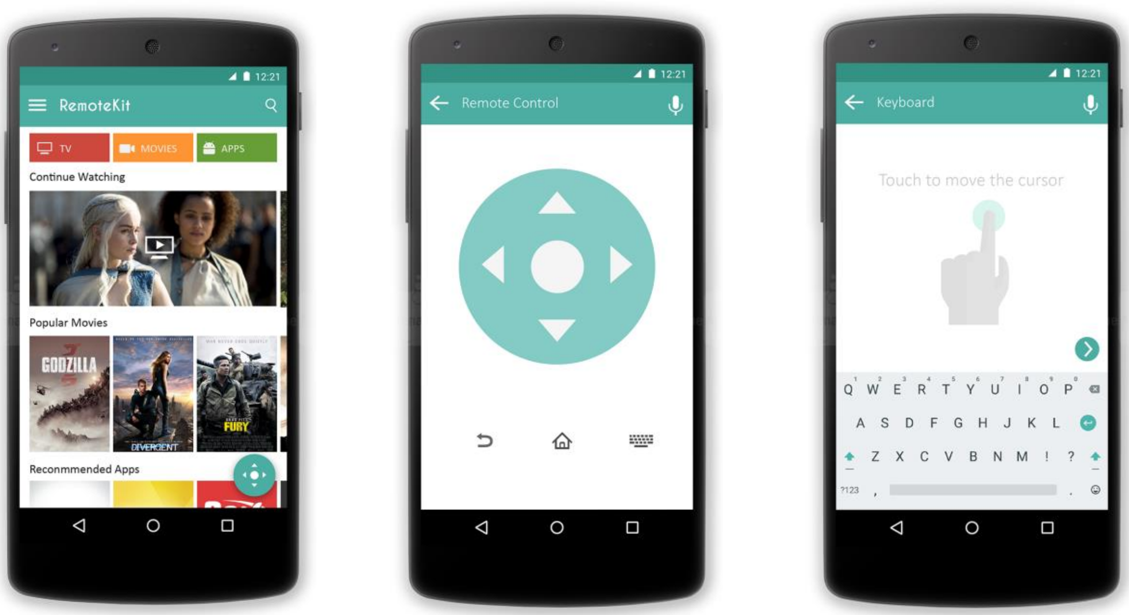


Figure 8: Mobile app user interface proposed for text entry and edit on smart TVs. (a) Home screen, showing all features of this app; (b) Remote control function which includes keyboards (keyboard buttons) and traditional controls; (c) The core function for text entry and editing which combines touch gestures (top blank area) and the smartphone virtual keyboard (bottom area).

In addition to the text entry and edit functions, this mobile app also provides some other functions related to smart TVs. In this app, there is an interface with arrow buttons which allows users to use this app as a traditional remote control (Fig. 8(b)). Using this app, users can browse and search movies or shows on the phone and play them by selecting them on the phone (Fig. 8(a)). This feature reduces the time it takes users to type on a smart TV because users can search information directly on a smartphone instead of on the smart TV.

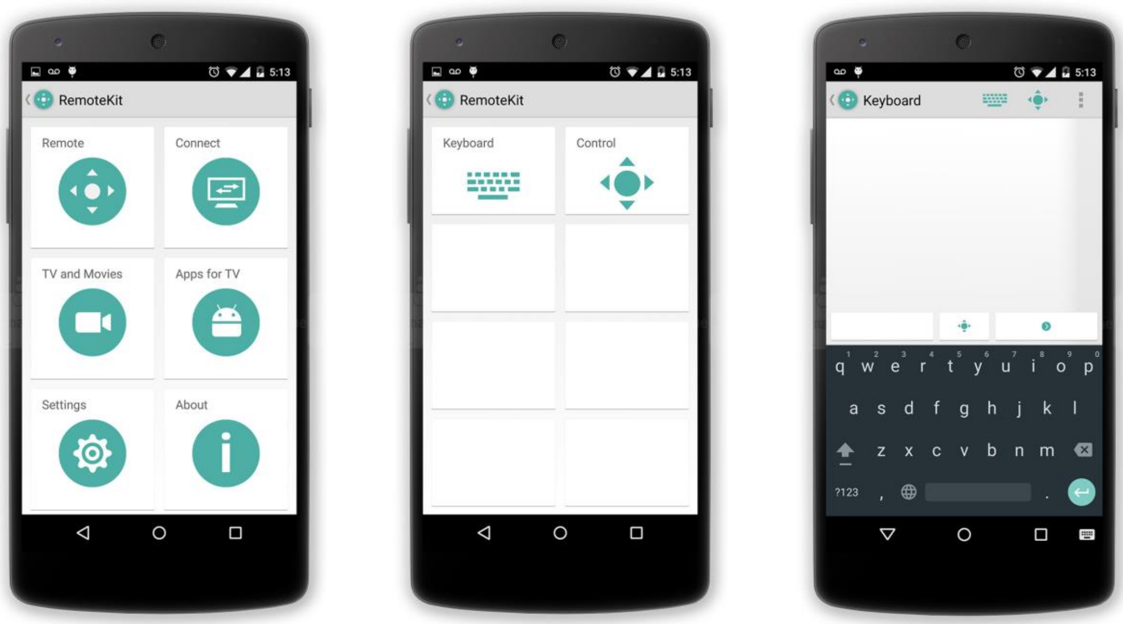


Figure 9: Functional prototype for user testing. (a) Home screen, showing all features of this app; (b) Remote control function which includes keyboards and traditional controls; (c) The keyboard function which combines touch gestures (top blank area) and a smartphone virtual keyboard (bottom area).

Prototype Development

A functional prototype (Fig. 9) was developed for further user testing in this study. At beginning the first prototype developed was based on mobile Android system and Amazon Fire TV platform. However, the data from the app could not be fully supported by Amazon set-top box platform. The second round prototyping was based on Android system and Windows system. The mobile app was developed on the Android system. Technically, the data for typing and editing text was gathered from the mobile app on an Android smartphone and sent to a Windows system laptop via WiFi network. The laptop sent data to a digital TV through HDMI cable. The mobile app was developed under the Android 5.0 system using Android Studio and Eclipse. The earlier prototype was tested on Eclipse. The final prototype was installed and tested on a Google Nexus 5 smartphone.

The next step following this chapter was to come up with ways to evaluate the effects of this prototype compared to current input methods on smart TVs.

CHAPTER 4

METHODOLOGY

Hypothesis

This research compares current text entry and edit methods with the new method as mentioned last chapter which combines smartphone touch gestures and a virtual keyboard to find out which one is the most efficient method and which one has the maximum user satisfaction. If the new method of text entry and editing takes less time than current methods, it can be concluded that it is more efficient to use smartphone touch gestures and virtual keyboards as a text entry and edit method for smart TVs. If the user satisfaction from the new method is higher than current methods, then the new method may offer better user experience than current methods.

To test the hypothesis, this study asked users to test the new design proposed and compare it to current input methods. To provide a convincing result, the study included both self-report data from subjects and objective measure of time from the tester. The independent variables of the test were different text input methods, and the dependent variables were efficiency (time) and user satisfaction. Both qualitative data and quantitative data was collected. The quantitative data was the time subjects spent on using different input methods. This study compared and analyzed the time required for different input methods and determined whether the new design the new design was more effective for typing or editing text on smart TVs. The qualitative data was taken from the questionnaires completed by subjects. By analyzing the rate or score subjects gave to different input methods, the study compared which input method got the highest score to find out if the new design had higher user satisfaction than current methods.

Materials for Usability Testing

The main facility was a 50 inch LG digital television which supported smart TV boxes, like Amazon Fire TV, Google Chromecast. The text entry and edit methods that were tested include three current methods and the new method that has been proposed within this study. These three current methods were: a traditional TV remote control with an on-screen virtual keyboard; a touchpad with an on-screen virtual keyboard; a physical wireless keyboard. The remote control was selected because nearly all smart TV platforms used it as the main input method. The touchpad method was a general representative method for the smart TVs which were using touch gesture as main interactive way between users and TV. The physical keyboard was selected because it could represent general QWERTY inputting device for smart TVs. Therefore, these three selected methods were generally representative of the current smart TV text entry and edit methods.

Method 1(Current Design): Traditional TV remote control, subjects can use the up, down, left, right and OK button to select the keys of the virtual keyboard on TV to input/edit text. An Amazon Fire TV set-top box was chose as a representative of this method, because the main text entry and edit method for Amazon Fire TV is to use the arrow buttons on the remote control to interact with the on-screen keyboard.

Figure 10: Amazon Fire TV set-top box with a traditional remote control.

Figure 11: Amazon Fire TV on-screen keyboard user interface.

Method 2(Current Design): Touchpad, subjects can move their finger on the touchpad to select the letters of the virtual keyboard on TV to input/edit text. A mobile app was developed which provided such touch gesture interaction. An on-screen keyboard software was chosen which had the traditional keyboard interface. Subjects can hold the smartphone as a touchpad to input or edit text on TV. When subjects are moving their fingers on the touchpad, the phone will send users' touching data to a laptop, and then the laptop will send data to the TV. Users can see a mouse pointer on the TV screen, so that they can select keys from the on-screen keyboard.

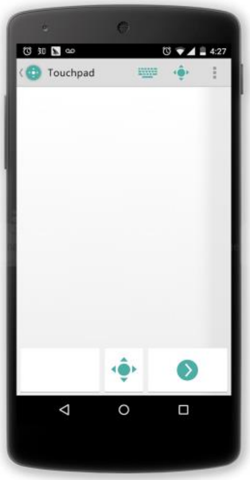


Figure 12: The mobile app that simulates Touchpad interaction, users can touch the center (blank) portions of the screen and use it as a Touchpad.

Figure 13: The virtual keyboard which can interact with Touchpad.

Method 3(Current Design): Physical TV keyboard, subjects can type/edit text on TV by pressing the letter buttons on the physical keyboard. Rii Mini Wireless Keyboard was chosen as the representative product for this input methods. The keyboard is small and can be held in the user’s hands.

Figure 14: Rii Mini Wireless Keyboard.

Method 4(The New Design): The mobile app prototype proposed within this study allows users to connect to and control their smart TV's with their smartphones. Subjects can use the virtual keyboards on the smartphone to type in text on smart TVs. Subjects can use touch gestures on the phone screen to control the movement of the cursor on smart TVs so they can edit the text no matter where the text is, and they can also use touch gestures to select, copy and paste text on smart TVs. In the app, subjects can switch between different keyboards by using slide gesture on the phone screen.

Pilot Study

A pilot study is a small scale preliminary study conducted in order to evaluate feasibility, time, cost, adverse events, and effect size (statistical variability) in an attempt to predict an appropriate sample size and improve upon the study design prior to performance of a full-scale research project[22]. Before conducting the formal user testing in this study, a pilot study was carried out to compare the same methods as mentioned above. Five users were recruited to do the pilot test, and each user was given a task to type a sentence onto smart TVs by using four input methods. The content of the sentence was "Game of Thrones is an American series created for HBO by David". This sentence was chosen because it contained a TV show's name and a person's name, which were the most frequent typing contents on smart TV platforms. The time users spent typing in each method was measured. The input methods were also evaluated by using a System Usability Scale Form filled by users after using each method. After the task, subjects were asked to fill out an open questionnaire asking about their feedback on the input methods they used and suggestions on the test procedure.

Figure 15: Pilot testing: a user was using Amazon Fire TV remote control to input the sentence provided by the tester.

After the pilot test, some changes were made based on the feedback. One of the biggest change was the length and content of the sentence inputted by users. The result showed that the time using physical keyboard and mobile app to input the original sentence was nearly the same, but when the sentence was made longer, the time of these two methods started to be different. Next, the original sentence was lengthened. During the testing, users did not input any numbers and symbols which may cause one-sided result for the overall evaluation on different methods. Therefore some symbols and numbers were added into the sentence. The final content of the sentence for user testing was “Game of Thrones is an American series created for HBO by David. Contact: David083@gmail.com; #394-209-9275”.

Three users mentioned that the font sizes of the sentence showing on the screen were too small which might slow down their typing speed. Thus the font size displayed on the TV was enlarged.

Subjects

The study was conducted at College of Architecture on Georgia Institute of Technology campus with a sample of 20 currently enrolled college students. All subjects were aged 18 or over. All participants had at least one year of experience using smartphones. Similarly each participant had at least a year's experience watching TV. Each user did the test individually.

Before the test began, each subject was asked to read and sign a consent form approved by Georgia Tech IRB.

Each subject was given a $10 Walmart gift card as compensation for participating in this study.

20 subjects were chosen for this research since when collecting usability metrics, testing 20 users typically offers a reasonably tight confidence interval. With 20 users, there would probably be one outlier (since 6% of users are outliers), so the result would include data from 19 users in average. This made the confidence interval go from 243 to 357 seconds, since the margin of error was +/- 19% for testing 19 users. In practice, a confidence interval of +/- 19% was ample for most goals.

Usability Tasks

The experiment was organized in 2 sessions per participant. There were four tasks for each session. In session 1, each participant was asked to do four tasks related to text entry on the smart TV. In session 2, each participant was asked to do four tasks related to text editing on the smart TV.

Session 1-Task 1: The participant was asked to get familiar with Amazon Fire TV remote control and learn how to type a character, number and symbol, and how to switch between lower and upper case. Then the participant was asked to type a sentence showed on a piece of paper onto the smart TV.

Session 1-Task 2: The participant was asked to learn how to use the Touchpad input method and try to type a character, number and symbol, switch between lower and upper case. Then the participant was asked to type the same sentence onto the smart TV.

Session 1-Task 3: The participant was given a Rii Wireless Keyboard and asked to get familiar with it and learn how to type a character, number and symbol, and how to switch between lower and upper case. Then the participant was asked to type the same sentence onto the smart TV by using this method.

Session 1-Task 4: The participant was asked to get familiar with the mobile app this study proposed and try to type a character, number and symbol, and how to switch between lower and upper case by using this app. Then the participant was asked to type the same sentence onto the smart TV.

Session 2-Task 1: The participant was asked to try to use Amazon Fire TV remote control to edit text on the smart TV. Once the participant got familiar with this method, the participant was asked to edit a sentence on the smart TV following instructions printed on a piece of paper.

Session 2-Task 2: The participant was asked to learn how to use the Touchpad to edit text on the smart TV. Then the participant was asked to edit the same sentence on the smart TV following the same instructions as previous task.

Session 2-Task 3: The participant was given a Rii Wireless Keyboard and asked to try to use it to edit text on the smart TV. Then the participant was asked to edit the same sentence on the smart TV following the same instructions as previous task.

Session 2-Task 4: The participant was asked to get familiar with the mobile app this study proposed and try to edit text on the smart TV by using this method. Then the participant was asked to edit the same sentence on the smart TV following the same instructions as previous task.

As mentioned above, a training task was performed before each main task. For session 1, the training task was to type a short sentence- “Game of Thrones @ 5-2 channel”. For session 2, the training task was to edit the sentence- “Game of Thrones @ 5-2 channel” and change it to sentence- “Game of Thrones @ 7-2 HBO”. The purpose of this training task was to let participants get familiar with each text entry and edit method.

For session 1, the sentence participants were asked to input in the main task was “Game of Thrones is an American series created for HBO by David. Contact: David083@gmail.com; #394-209-9275”. For session 2, participants were asked to edit sentence “Game of Thrones is an American series created for HBO by David. Contact: David083@gmail.com; #394-209-9275” and change it to “Game of Thrones is a fantasy drama created for HBO by Dave. Contact:Dave083@gmail.com;   #394-259-9275” in the main task.

Setup for Users Testing

The user testing was conducted at a graduate studio in the College of Architecture building on Georgia Institute of Technology campus. All the test facilities were put in an empty space. A LG 50 inch digital television which supported smart TV boxes was put in this space. Devices for text entry and edit methods included: (1) Lenovo Y510P laptop for exchanging data between TV and smartphone app; (2) iPad for timing; (3) Google Nexus 5 smartphone; (4) Rii Mini Wireless keyboard; (5) Amazon Fire TV set-top box.

Figure 16: The empty space with a LG 50 inch digital TV for user testing.

User Testing Procedures

In this user testing, 20 participants were tested individually. Prior to testing, the participants were asked to fill a pre-test questionnaire (Appendix A) about their basic information—including experience of using smart TVs and smartphones. Then participants were oriented to the experimental procedures.

The experiment was organized in 2 sessions per participant. The procedures took approximately 40 minutes to 60 minutes. The order in which tasks were tested in each session was randomly selected for each participant (Appendix B), and the purpose was to counterbalance the effects of learning. The participants were asked to sit on a chair about 7 feet in front of the TV.

Session 1: The subject was given a sentence which included letters, numbers and symbols. The sentence was printed on a piece of paper on the desk in front of subject's seat. The subject was asked to use an Amazon Fire TV remote control, a Touchpad and a Rii mini wireless keyboard and the mobile app this study proposed to type the given sentence onto the TV screen (four tasks as we mentioned). The subject was told to finish each task as fast and correctly as possible. The time the subject spent on each task was measured. After each task, the subject was asked to fill a RAW TLX Form and a System Usability Scale Form.

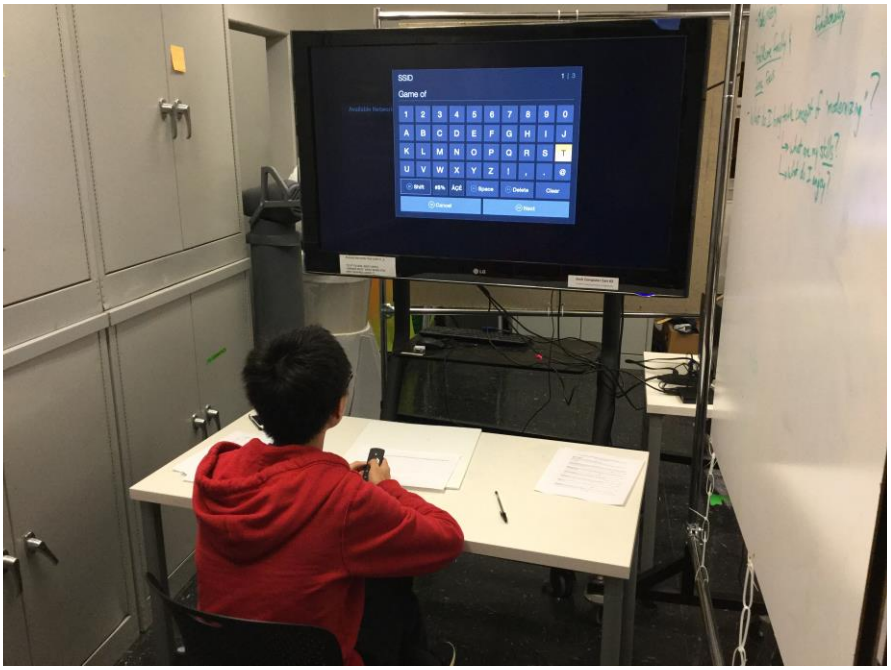


Figure 17: A participant was doing Task 1 in Session 1 (Amazon Fire TV remote control).

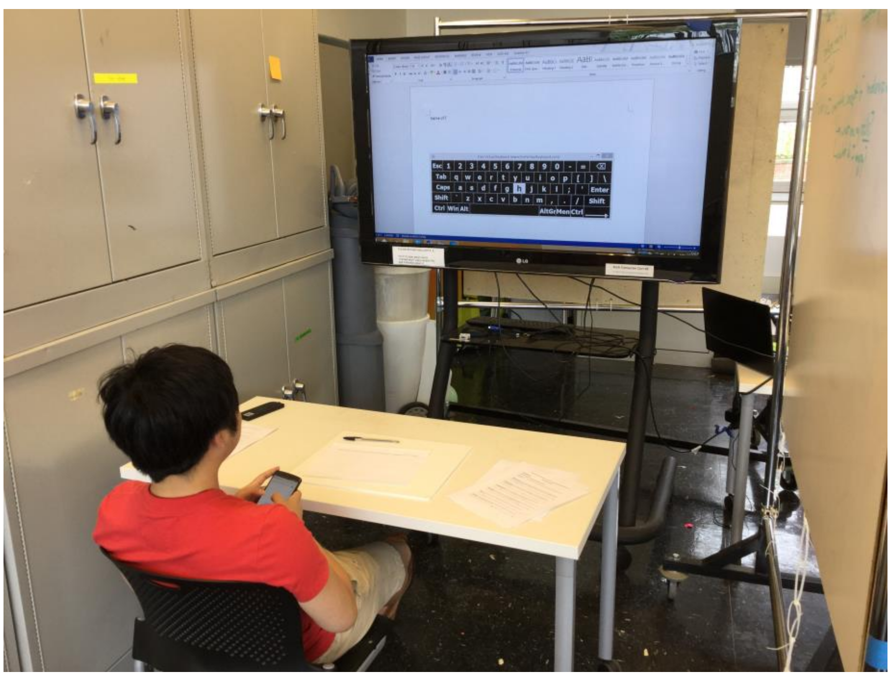


Figure 18: A participant was doing Task 2 in Session 1 (Touchpad).

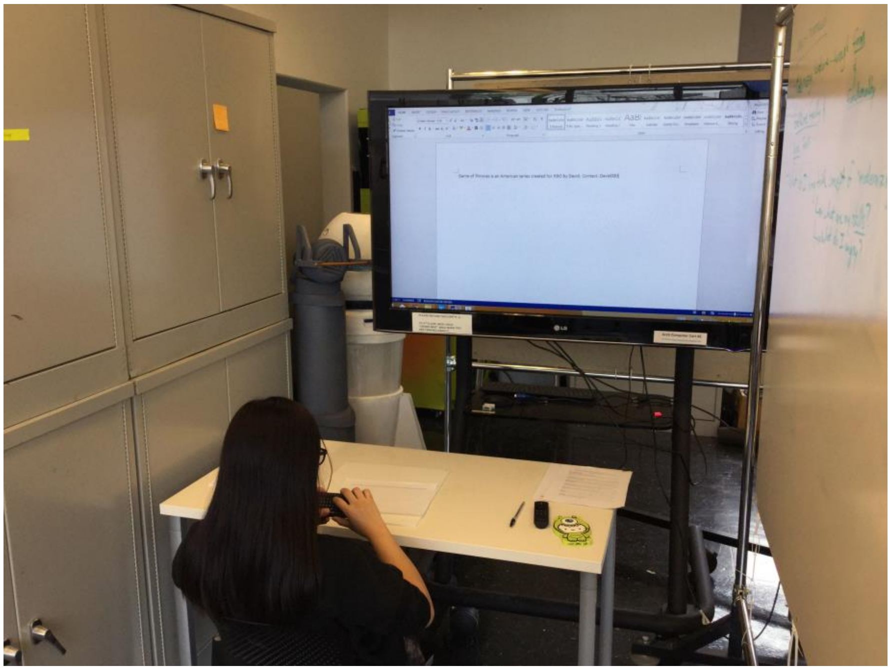


Figure 19: A participant was doing Task 3 in Session 1 (Rii mini wireless keyboard).

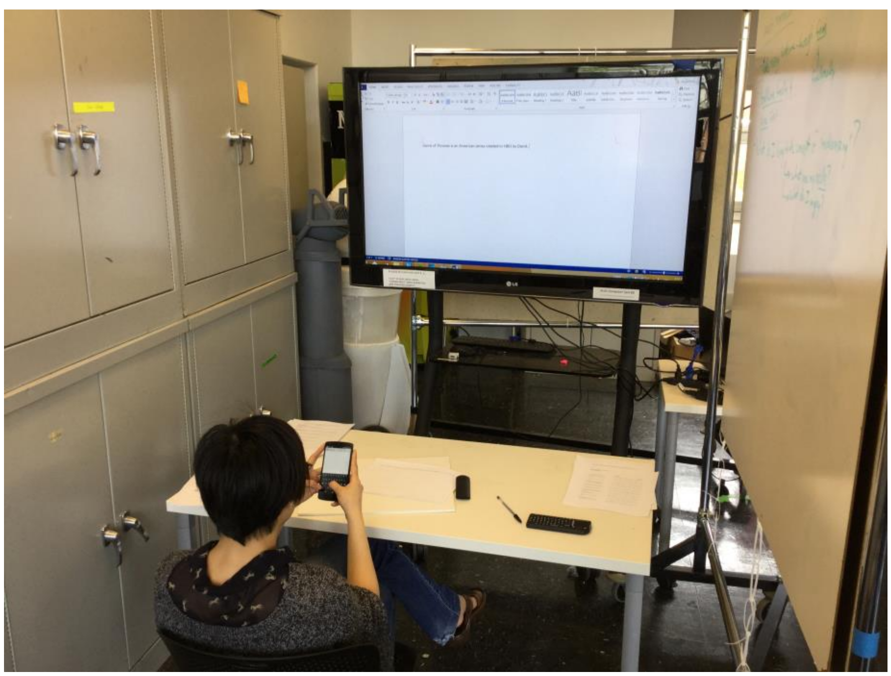


Figure 20: A participant was doing Task 4 in Session 1 (Mobile app we designed).

Session 2: A sentence which included letters, numbers and symbols was shown on TV, but there were several typing errors in the sentence. The correct sentence was printed on a piece of paper on the desk in front of subject's seat. The subject was asked to use an Amazon Fire TV remote control, a Touchpad and a Rii mini wireless keyboard and the mobile app we designed to correct the sentence on TV screen. The subject was not allowed to clear the whole sentence but had to correct certain letters/numbers/symbols in the sentence. The time the subject spent on each task was measured. After using each method, the subject was asked to fill a RAW TLX Form and a System Usability Scale Form.

After the participants finished each session, they were asked to complete a Session Overall Review Form to evaluate different text entry and edit methods for smart TVs.

CHAPTER 5

DATA ANALYSIS AND RESULTS

As mentioned in the previous chapter, a user evaluation test was conducted. Both subjective and objective data was gathered from 20 subjects, and all the data was used in the analysis.

Pre-test Questionnaire Data

Based on the data gathered from pre-test questionnaire, the results show that the subjects had an average 5.6 years of using smartphone, and 50% of them had ever used smart TVs, but only 35% of them had ever used any input device to type text onto TV.

Error Rates

During the user testing, all 20 subjects completed all tasks. Only 5 participants produced an error in one of the tasks. Most of the errors were made in session one. Errors were made with each of the input methods. The error rate of each input method was 0.0023 on average. Since the error rate was very low, the data of error was not discussed in this study.

Tasks Data from Session 1

The data from Session 1 included both objective data measured by the tester and subjective data taken from subjects. The objective data was the time each subject spent on completing a task and it reflected the text entry efficiency of each input method. The subjective data was from post-test questionnaires, RAW TLX Form, System Usability Scale Form, and Overall Self-reported Form.

Completion Time Result

Table 1 summarized the result of the completion time of each task by each participant. A one way ANOVA (Completion Time* Task) was applied to the data (Appendix H). There were statistically significant differences between group means as determined by the one-way ANOVA ($F = 157.446$, $p = 0.000$). Next, Post Hoc Tests were run to confirm where the differences occurred between groups (Appendix H). The results show: there were significant differences between the new design (Task 4) and the traditional remote control (Task 1) ($p= 0.000$) and the touchpad (Task 2) ($p= 0.000$). There was no significant difference between the new design and the physical keyboard (Task 3) ($p= 0.572$), or between the traditional remote control and the touchpad ($p= 0.094$).

Table 1: Completion time (seconds) of each task by each participant in Session 1.

	SESSION 1			
	TASK 1	TASK 2	TASK 3	TASK 4
User T1	340	350	85	83
User T2	392	374	109	120
User T3	364	285	151	105
User T4	268	275	98	62
User T5	327	384	147	78
User T6	262	220	81	75
User T7	366	332	125	90
User T8	353	306	130	105
User T9	380	276	95	84
User T10	337	345	123	92
User T11	386	438	115	112
User T12	379	392	93	107
User T13	218	136	74	79
User T14	262	236	109	81
User T15	329	461	107	71
User T16	305	323	98	92
User T17	332	310	106	98
User T18	360	348	110	87
User T19	290	269	92	79
User T20	335	356	127	95

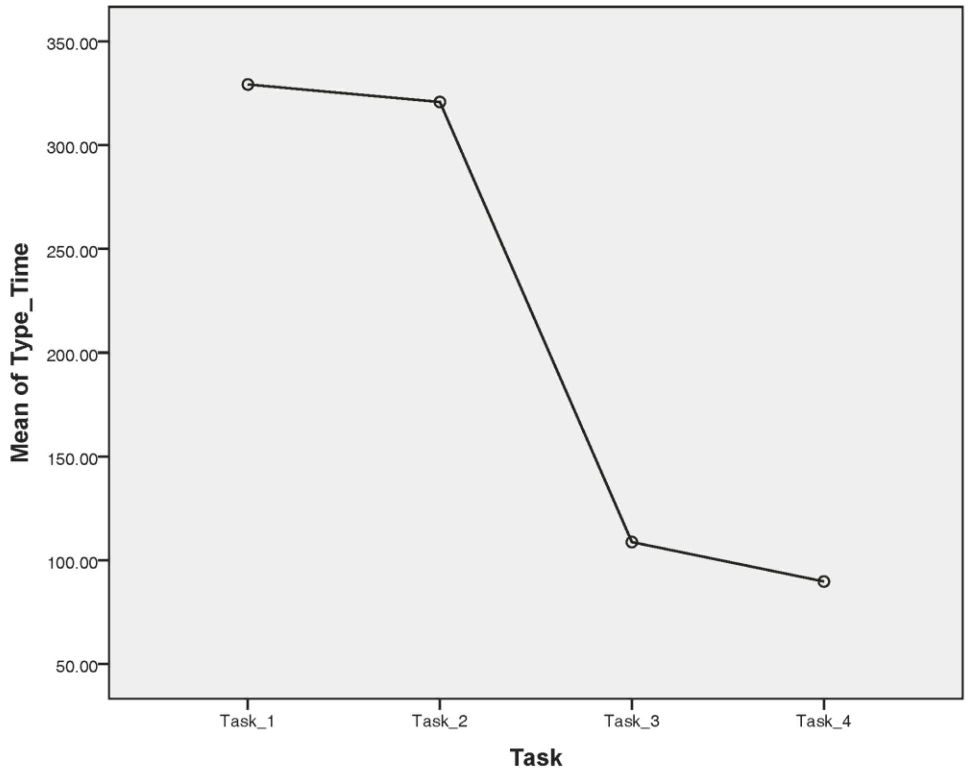


Figure 21: Completion time (seconds) of each task in Session 1.

RAW-TLX Scores Result

Table 2 summarized the results of the RAW-TLX Score data in Session 1. Raw TLX is recommended as a simple alternative to the traditional NASA TLX. The Raw TLX does not require task paired comparison weights as it is based upon a simple sum of scales. The lowest rating reflected the best user satisfaction. The Figure 22 showed that Task 4 in Session 1 had the lowest rating score. The results from the one-way ANOVA (RAW-TLX score* Task) and Post Hoc Tests (Appendix I) show that there were significant differences between the new design (Task 4) and the traditional remote control (Task 1) (p= 0.000) and the touchpad (Task 2) (p= 0.000). There was no significant difference between the new design and the physical keyboard (Task 3) (p= 0.991).

Table 2: RAW-TLX Ratings of each task by each participant in Session 1.

TASK 1	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL		TASK 2	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL
User 1	6	10	11	1	16	4	48		User 1	11	11	7	3	14	3	49
User 2	5	16	20	13	17	12	83		User 2	7	9	14	9	14	4	57
User 3	3	18	18	1	17	9	66		User 3	16	3	5	17	11	16	68
User 4	1	12	8	6	12	4	43		User 4	2	16	14	8	14	12	66
User 5	7	14	3	3	11	5	43		User 5	8	14	18	17	11	19	87
User 6	6	4	14	15	14	11	64		User 6	5	10	12	7	13	11	58
User 7	11	4	7	16	4	18	60		User 7	18	14	18	15	14	20	99
User 8	4	13	6	8	10	4	45		User 8	16	14	16	9	14	13	82
User 9	12	12	11	10	13	14	72		User 9	10	8	10	10	10	13	61
User 10	13	14	11	4	12	8	62		User 10	18	18	17	18	18	18	107
User 11	8	12	9	7	11	11	58		User 11	9	14	13	15	15	17	83
User 12	5	17	13	6	16	6	63		User 12	3	20	19	17	19	19	97
User 13	4	1	4	4	4	4	21		User 13	0	2	1	1	2	1	7
User 14	8	18	14	10	14	16	80		User 14	6	6	4	2	6	4	28
User 15	8	10	8	5	5	8	44		User 15	17	19	19	18	19	20	112
User 16	1	4	0	6	7	4	22		User 16	13	16	2	7	14	14	66
User 17	7	9	10	8	12	4	50		User 17	9	18	14	11	13	13	78
User 18	9	8	8	6	5	6	42		User 18	10	14	9	10	15	11	69
User 19	4	17	18	10	14	5	68		User 19	8	12	8	9	14	3	54
User 20	8	12	11	9	13	6	59		User 20	11	16	17	14	13	8	79
TASK3	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL		TASK 4	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL
User 1	4	3	2	2	2	0	13		User 1	2	2	1	0	1	0	6
User 2	3	8	5	5	4	1	26		User 2	7	8	10	6	9	6	46
User 3	2	2	2	2	11	3	22		User 3	1	1	1	2	4	3	12
User 4	0	4	4	4	4	2	18		User 4	0	0	4	2	2	2	10
User 5	3	12	6	5	11	8	45		User 5	1	3	1	1	3	2	11
User 6	3	7	3	3	5	2	23		User 6	9	6	3	4	3	2	27
User 7	13	10	2	7	5	1	38		User 7	11	1	5	2	6	4	29
User 8	6	10	2	7	8	5	38		User 8	10	12	5	13	6	5	51
User 9	7	12	7	9	6	13	54		User 9	6	4	4	6	6	6	32
User 10	9	7	9	5	6	6	42		User 10	2	2	2	1	2	2	11
User 11	6	8	4	7	4	4	33		User 11	3	2	3	3	2	1	14
User 12	3	5	5	1	3	4	21		User 12	4	15	14	6	17	7	63
User 13	1	3	1	3	2	5	15		User 13	3	0	1	2	2	3	11
User 14	6	6	4	4	4	2	26		User 14	12	14	16	2	14	4	62
User 15	3	11	3	4	3	11	35		User 15	3	3	3	0	3	1	13
User 16	1	2	0	4	2	2	11		User 16	14	6	2	4	2	7	35
User 17	2	4	5	6	8	5	30		User 17	2	2	4	3	5	2	18
User 18	4	7	6	5	9	10	41		User 18	4	5	3	6	3	4	25
User 19	3	6	4	3	5	2	23		User 19	5	4	8	6	4	5	32
User 20	2	5	3	5	4	2	21		User 20	3	7	8	7	4	4	33

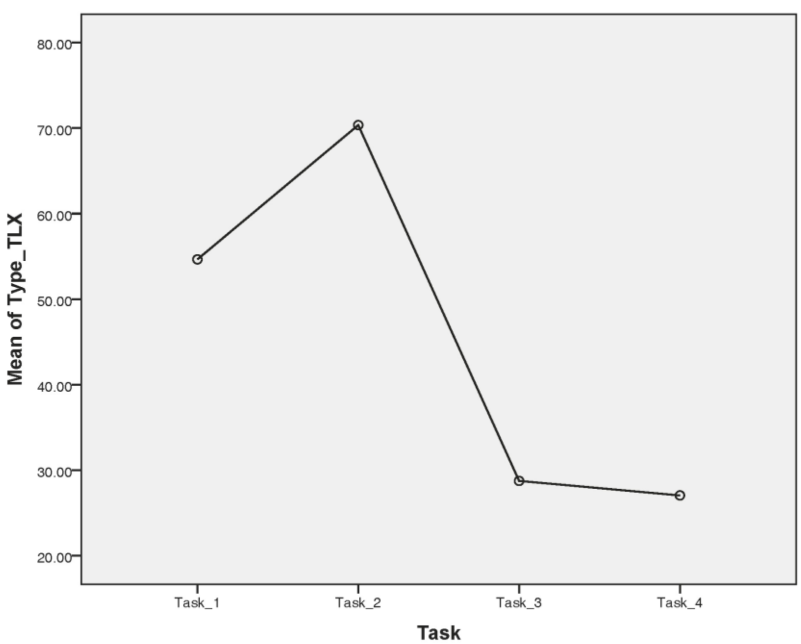


Figure 22: RAW-TLX score of each task in Session 1.

System Usability Scale Result

Table 3 summarized the result of the System Usability Scale (SUS) form score in Session 1. For odd items on the SUS form: score was same as the user response. For even-numbered items: subtracted the user responses from 6 to get the score. This scaled all values from 1 to 5 (with 5 being the most positive response). Next was to add up the converted responses for each user. The purpose of this study is to compare the difference between four methods, so the SUS score was not converted to 100 and all comparison was based on the original 0-50 scale. The highest score reflected the best user satisfaction. The results from the one-way ANOVA (SUS score* Task) and Post Hoc Tests (Appendix J) show that there were significant differences between the new design (Task 4) and the traditional remote control (Task 1) (p= 0.002) and the touchpad (Task 2) (p= 0.000). There was no significant difference between the new design and the physical keyboard (Task 3) (p= 0.953).

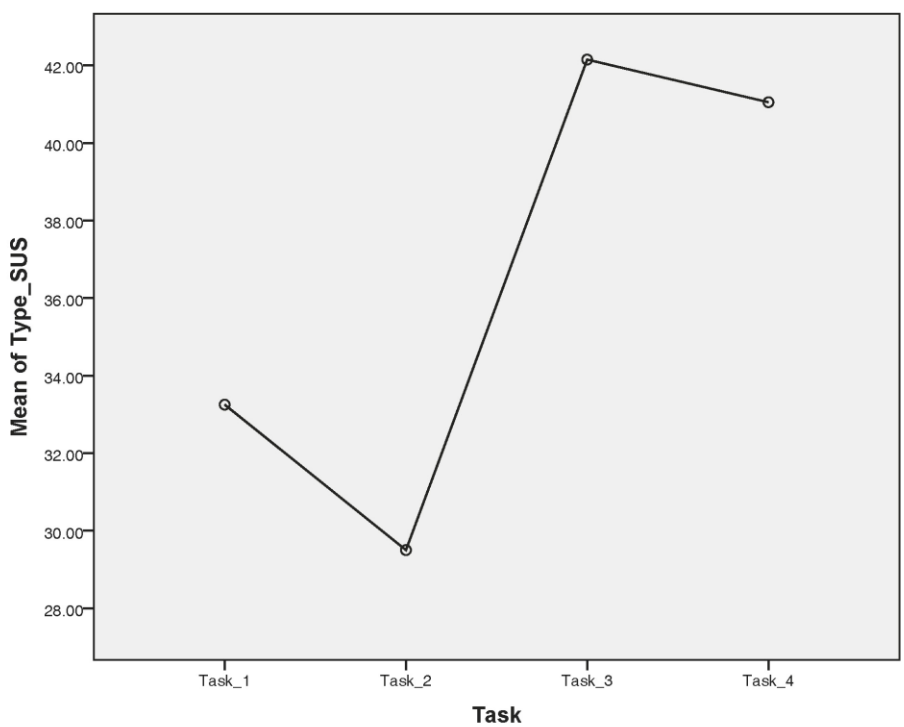


Figure 23: SUS form score of each task in Session 1.

Table 3: System Usability Scale of each task by each participant in Session 1.

TASK 1	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Score 8	Score 9	Score 10	TOTAL
User 1	1	1	1	5	2	2	4	2	4	5	27
User 2	2	2	1	4	2	3	4	1	3	4	26
User 3	3	4	2	5	4	4	5	3	5	5	40
User 4	3	3	4	5	3	2	4	2	4	5	35
User 5	4	4	4	4	4	4	4	4	4	4	40
User 6	1	2	5	3	2	4	1	2	2	3	25
User 7	3	5	5	5	4	2	5	3	3	5	40
User 8	3	4	2	5	3	5	2	4	4	5	37
User 9	1	1	1	4	2	2	4	2	2	3	22
User 10	4	3	4	5	5	5	5	4	5	5	45
User 11	1	2	3	4	3	2	4	2	3	5	29
User 12	2	2	2	4	3	3	4	2	4	5	31
User 13	3	2	4	5	3	2	3	1	4	5	32
User 14	2	2	2	4	2	3	4	2	3	4	28
User 15	3	4	3	5	3	4	4	4	4	5	39
User 16	3	4	4	5	3	3	4	2	4	5	37
User 17	2	4	3	5	2	2	3	3	2	4	30
User 18	1	5	2	5	3	2	4	4	5	5	36
User 19	2	4	3	5	2	3	4	3	4	4	34
User 20	2	3	4	4	3	3	2	4	3	4	32
TASK 2	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Score 8	Score 9	Score 10	TOTAL
User 1	1	1	1	5	2	3	4	1	4	5	27
User 2	4	3	3	5	3	4	4	3	3	4	36
User 3	3	5	3	5	4	4	5	2	3	5	39
User 4	3	3	2	4	2	2	3	3	3	5	30
User 5	1	3	2	5	3	3	4	1	1	5	28
User 6	1	2	2	4	1	2	2	3	3	4	24
User 7	3	3	2	5	3	3	5	1	4	5	34
User 8	2	4	2	5	3	4	2	3	3	5	33
User 9	1	1	1	5	3	2	4	1	2	4	24
User 10	1	1	1	4	1	1	4	1	1	5	20
User 11	1	2	2	4	3	3	3	2	2	4	26
User 12	1	1	1	3	2	2	1	1	1	2	15
User 13	5	5	5	5	5	4	3	5	5	5	47
User 14	4	4	4	3	4	4	4	4	4	4	39
User 15	1	1	1	5	2	3	4	1	2	5	25
User 16	1	2	2	2	1	3	4	1	4	5	25
User 17	2	3	2	5	3	4	4	2	3	5	33
User 18	1	2	1	3	3	4	3	2	4	4	27
User 19	2	2	3	4	4	3	3	2	3	4	30
User 20	1	3	2	4	3	3	3	2	3	4	28
TASK 3	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Score 8	Score 9	Score 10	TOTAL
User 1	5	5	5	5	5	5	5	5	5	5	50
User 2	5	4	5	5	4	4	4	4	5	3	43
User 3	4	4	5	5	4	4	5	5	4	5	45
User 4	3	4	4	5	4	4	5	3	5	5	42
User 5	3	4	3	5	2	2	4	3	4	4	34
User 6	5	5	5	5	4	5	4	4	5	5	47
User 7	5	5	5	5	3	4	5	4	5	5	46
User 8	4	3	4	5	3	5	2	4	4	5	39
User 9	1	2	3	4	2	2	3	2	3	4	26
User 10	4	3	5	5	4	4	5	4	5	5	44
User 11	3	4	4	5	3	3	4	4	4	5	39
User 12	5	4	5	4	4	4	5	5	5	5	46
User 13	4	4	5	5	5	5	4	4	5	5	46
User 14	4	4	4	4	3	4	4	4	5	4	40
User 15	4	4	5	5	4	3	5	4	5	5	44
User 16	4	4	5	5	4	4	4	4	5	5	44
User 17	5	5	4	5	4	3	4	5	5	5	45
User 18	4	4	4	5	4	3	3	5	4	4	40
User 19	3	3	5	5	3	4	4	3	4	5	39
User 20	4	5	4	3	4	5	5	4	5	5	44
TASK 4	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Score 8	Score 9	Score 10	TOTAL
User 1	5	5	5	5	4	5	5	5	5	5	49
User 2	4	3	4	4	3	4	3	3	4	5	37
User 3	5	5	5	5	5	5	5	5	5	5	50
User 4	5	4	5	5	4	4	5	4	5	5	46
User 5	5	5	5	5	4	4	5	5	5	5	48
User 6	4	5	4	5	4	5	4	4	4	5	44
User 7	5	5	5	5	4	4	5	5	5	5	48
User 8	4	3	3	5	1	4	2	4	4	5	35
User 9	1	2	2	4	2	2	4	1	3	4	25
User 10	5	5	5	5	5	5	5	5	5	5	50
User 11	4	5	4	5	3	4	5	5	5	5	45
User 12	1	2	1	3	4	3	4	2	2	4	26
User 13	4	4	5	4	4	4	4	4	2	5	40
User 14	3	2	4	4	3	4	4	4	4	4	36
User 15	5	4	5	5	4	5	5	5	5	5	48
User 16	1	2	2	5	2	3	4	2	4	5	30
User 17	5	4	3	4	4	5	4	4	4	5	42
User 18	4	5	3	4	5	4	4	5	5	5	44
User 19	4	3	4	4	5	4	3	3	4	4	38
User 20	4	3	4	5	4	3	4	4	4	5	40

Overall Self-reported Form Result

Table 4 summarized the result of the Overall Self-reported score for each task by each subject in Session 1. The highest score reflected the best user satisfaction. The results from the one-way ANOVA (Overall score* Task) and Post Hoc Tests (Appendix K) show that there were significant differences between the new design (Task 4) and the traditional remote control (Task 1) (p= 0.000) and the touchpad (Task 2) (p= 0.000). There was no significant difference between the new design and the physical keyboard (Task 3) (p= 0.984).

Table 4: Overall Self-reported score of each task by each participant in Session 1

	SESSION 1			
	TASK 1	TASK 2	TASK 3	TASK 4
User S1	1	4	9	8
User S2	1	2	8	6
User S3	5	6	7	10
User S4	4	10	8	10
User S5	7	2	4	9
User S6	1	3	9	6
User S7	7	1	9	8
User S8	8	6	7	7
User S9	2	1	3	4
User S10	5	1	7	10
User S11	4	2	8	9
User S12	4	1	8	3
User S13	3	8	8	6
User S14	2	7	8	4
User S15	5	1	8	10
User S16	7	5	8	5
User S17	5	3	6	8
User S18	1	4	7	8
User S19	6	3	8	6
User S20	5	5	9	7

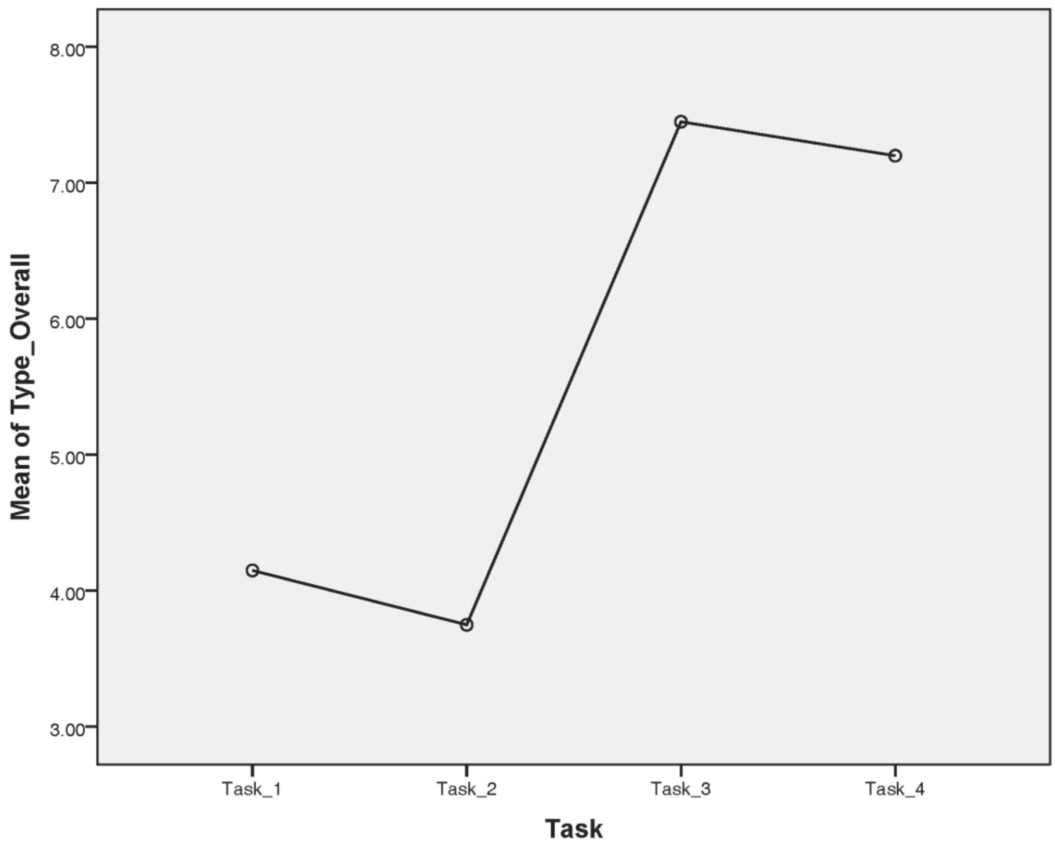


Figure 24: Overall Self-reported score of each task in Session 1.

Tasks Data from Session 2

As in Session 1, the data from Session 2 included both objective data measured by the tester and subjective data was taken from subjects. The objective data was the time each subject spent on completing a task and it reflected the text editing efficiency of each input method. The subjective data was from post-test questionnaires, RAW TLX Form, System Usability Scale Form, and Overall Self-reported Form.

Completion Time Result

Table 5 summarized the result of the completion time of each task. The results from the one-way ANOVA (Completion time* Task) and Post Hoc Tests (Appendix L) show that there were significant differences between the new design (Task 4) and the traditional remote control (Task 1) (p= 0.000) and the touchpad (Task 2) (p= 0.000). There were also significant differences between the traditional remote control and the touchpad (p= 0.000). However, there was no significant difference between the new design and the physical keyboard (Task 3) (p= 0.986).

Table 5: Completion time (seconds) of each task by each participant in Session 2.

	SESSION 2			
	TASK 1	TASK 2	TASK 3	TASK 4
User T1	296	120	38	27
User T2	341	111	54	37
User T3	312	101	57	48
User T4	230	75	33	35
User T5	283	87	42	37
User T6	233	52	28	26
User T7	317	82	66	54
User T8	307	106	51	37
User T9	382	84	44	50
User T10	293	73	49	35
User T11	331	97	46	45
User T12	331	110	57	84
User T13	210	55	42	30
User T14	231	65	33	45
User T15	289	122	51	40
User T16	263	84	43	62
User T17	302	95	52	51
User T18	298	83	47	44
User T19	306	93	49	46
User T20	276	85	36	32

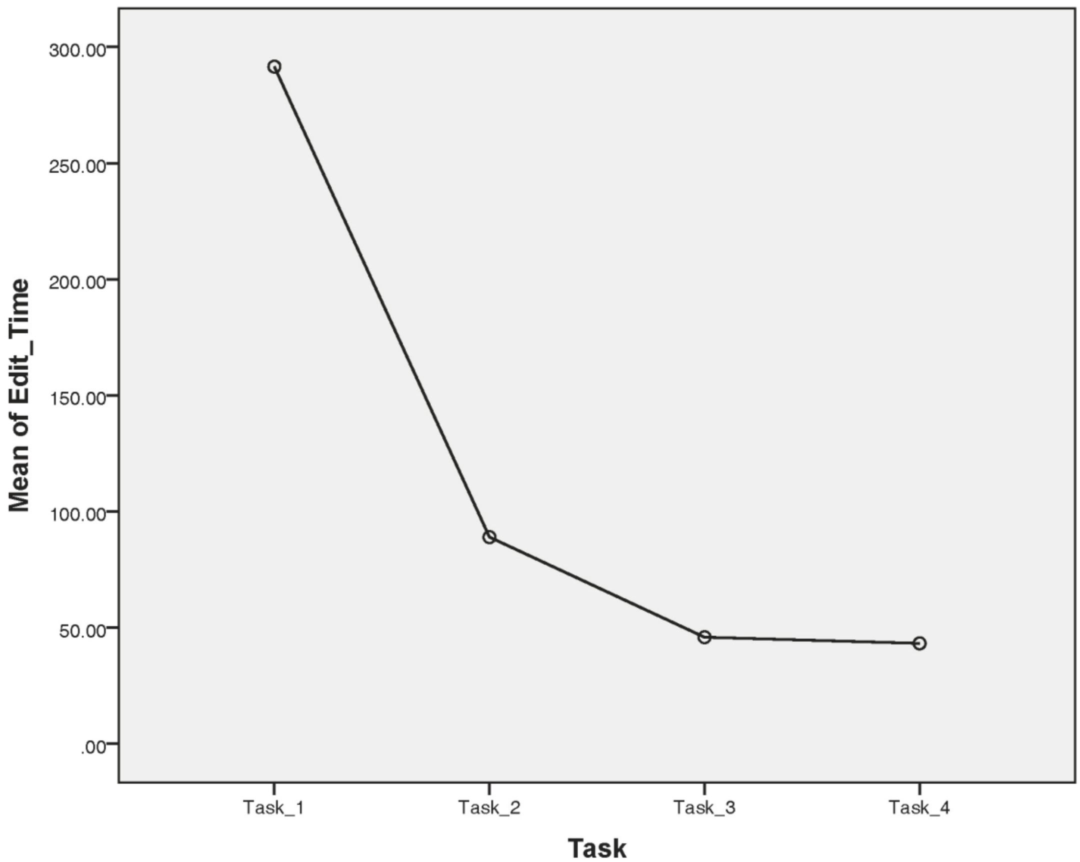


Figure 25: Completion time (seconds) of each task in Session 2.

RAW-TLX Scores Result

Table 6 summarized the result of the RAW-TLX Score data in Session 2. The lowest rating reflected the best user satisfaction. The results from the one-way ANOVA (RAW-TLX score* Task) and Post Hoc Tests (Appendix M) show that there were significant differences between the new design (Task 4) and the traditional remote control (Task 1) (p= 0.000) and the touchpad (Task 2) (p= 0.002). There were also significant differences between the traditional remote control and the touchpad (p= 0.001). However, there was no significant difference between the new design and the physical keyboard (Task 3) (p= 1.000).

Table 6: RAW-TLX Ratings of each task by each participant in Session 2.

TASK 1	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL
User 1	6	12	14	0	17	5	54
User 2	8	8	15	7	9	7	54
User 3	5	17	17	10	16	11	76
User 4	6	14	14	8	16	16	74
User 5	16	19	19	11	19	19	103
User 6	18	18	17	14	17	14	98
User 7	3	17	5	9	14	15	63
User 8	4	18	12	6	14	18	72
User 9	8	11	8	9	7	7	50
User 10	6	18	16	18	16	16	90
User 11	2	6	10	8	4	10	40
User 12	3	18	18	16	18	15	88
User 13	2	0	2	4	2	2	12
User 14	10	18	6	16	16	12	78
User 15	16	16	16	10	14	16	88
User 16	2	16	1	9	15	14	57
User 17	6	15	15	11	13	8	68
User 18	10	13	12	11	18	19	83
User 19	9	16	17	14	12	8	76
User 20	5	13	12	13	12	17	72

TASK 2	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL
User 1	6	6	3	2	11	1	29
User 2	7	10	7	5	11	5	45
User 3	2	2	3	3	7	8	25
User 4	2	8	6	2	6	6	30
User 5	3	6	5	9	8	4	35
User 6	7	7	10	10	12	10	56
User 7	6	16	11	10	10	10	63
User 8	14	7	3	10	10	10	54
User 9	11	12	12	11	11	14	71
User 10	4	12	13	8	14	13	64
User 11	4	3	4	12	4	8	35
User 12	7	18	6	16	18	18	83
User 13	0	0	1	0	0	0	1
User 14	6	4	6	8	10	4	38
User 15	20	20	14	19	18	3	94
User 16	2	2	0	5	3	6	18
User 17	4	10	12	10	12	9	57
User 18	3	7	5	6	7	4	32
User 19	11	9	9	7	6	5	47
User 20	5	6	12	11	8	7	49

TASK3	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL
User 1	2	2	2	0	1	0	7
User 2	5	6	5	7	10	3	36
User 3	3	3	3	0	6	3	18
User 4	0	0	0	2	0	2	4
User 5	2	3	1	0	3	1	10
User 6	2	2	3	1	2	1	11
User 7	14	1	1	9	3	4	32
User 8	9	16	6	6	12	16	65
User 9	7	7	7	8	7	7	43
User 10	4	4	4	6	8	6	32
User 11	4	3	1	3	1	1	13
User 12	3	5	5	3	7	7	30
User 13	0	1	1	1	1	0	4
User 14	4	4	4	6	6	4	28
User 15	5	7	7	6	5	9	39
User 16	1	0	0	2	1	1	5
User 17	3	2	3	4	5	2	19
User 18	5	7	5	6	3	3	29
User 19	6	5	4	7	4	5	31
User 20	3	8	7	3	9	6	36

TASK 4	Q1	Q2	Q3	Q4	Q5	Q6	TOTAL
User 1	3	2	0	0	2	0	7
User 2	5	3	1	2	8	4	23
User 3	1	1	1	0	1	1	5
User 4	0	0	0	0	0	2	2
User 5	2	7	3	1	3	1	17
User 6	4	4	6	5	6	4	29
User 7	6	6	12	3	14	4	45
User 8	4	4	5	8	6	2	29
User 9	11	7	10	8	8	10	54
User 10	3	4	4	4	5	4	24
User 11	2	2	1	2	1	1	9
User 12	4	9	9	14	14	14	64
User 13	0	0	0	1	1	1	3
User 14	4	4	4	6	10	2	30
User 15	3	3	3	1	3	2	15
User 16	5	2	0	5	5	3	20
User 17	4	3	5	3	5	5	25
User 18	3	6	7	6	4	5	31
User 19	3	4	3	4	2	3	19
User 20	4	7	8	5	3	2	29

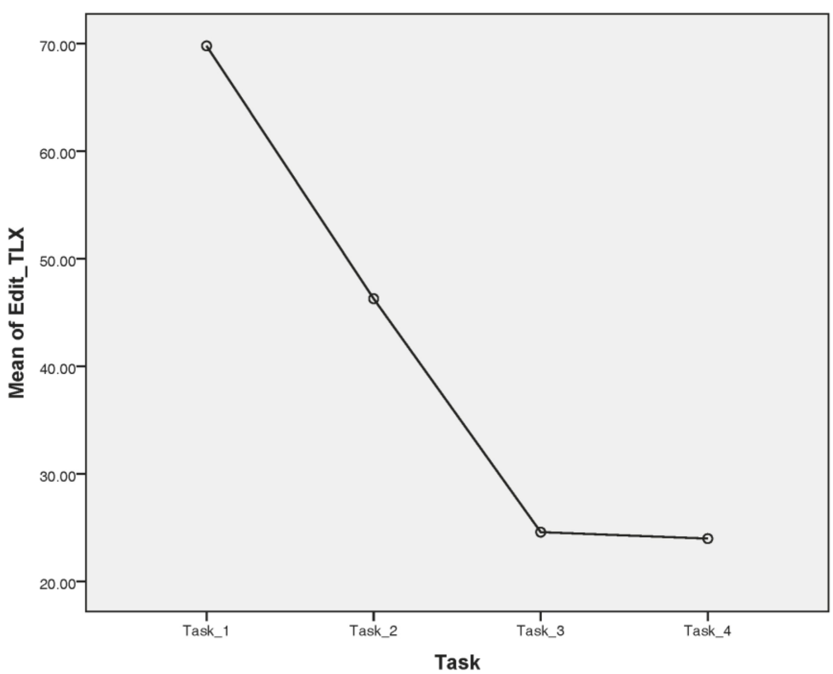


Figure 26: RAW-TLX score of each task in Session 2.

System Usability Scale Result

Table 7 summarized the result of the System Usability Scale (SUS) form score in Session 2. The highest score reflected the best user satisfaction. The results from the one-way ANOVA (SUS score* Task) and Post Hoc Tests (Appendix N) show that there were significant differences between the new design (Task 4) and the traditional remote control (Task 1) (p= 0.000) and the touchpad (Task 2) (p= 0.000). However, there was no significant difference between the new design and the physical keyboard (Task 3) (p= 0.999).

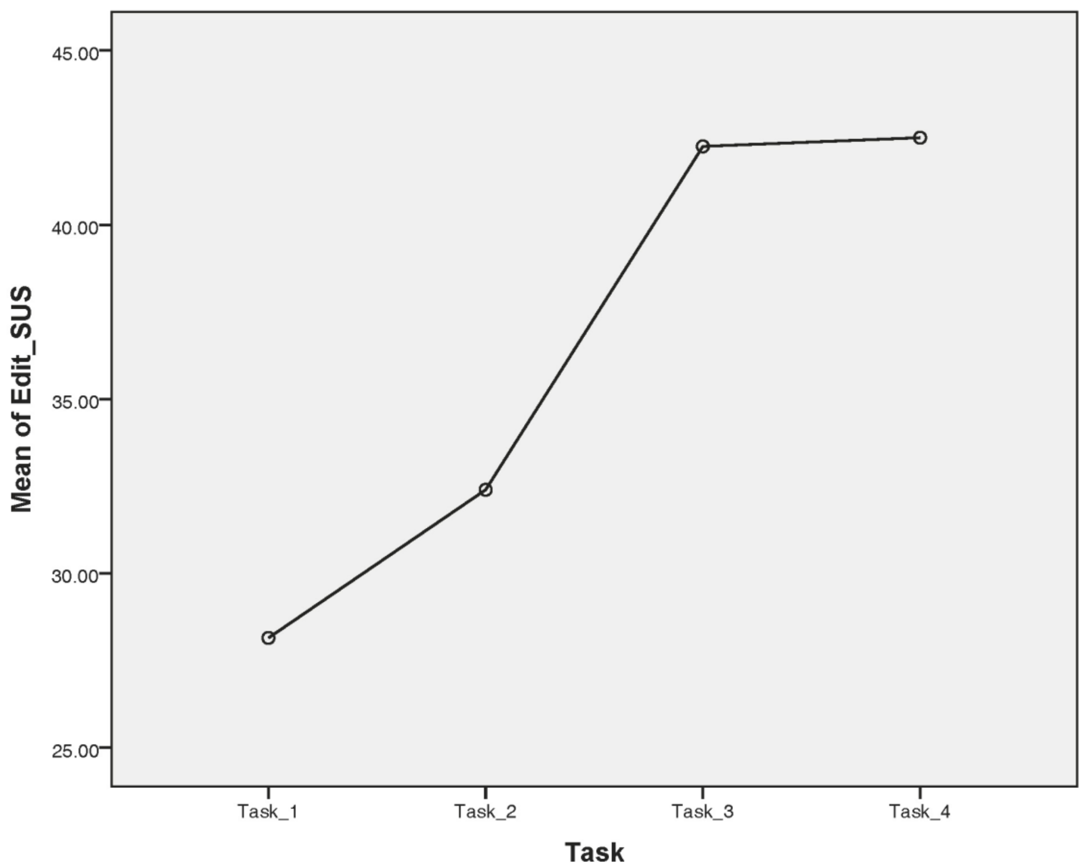


Figure 27: SUS form score of each task in Session 2.

Table 7: System Usability Scale of each task by each participant in Session 2.

TASK 1	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Score 8	Score 9	Score 10	TOTAL
User 1	1	1	1	5	1	3	3	2	3	5	25
User 2	3	3	2	3	2	3	4	3	3	4	30
User 3	2	3	3	4	2	3	4	3	3	4	31
User 4	1	1	1	4	3	1	3	3	3	3	23
User 5	1	1	1	5	2	3	4	1	2	5	25
User 6	1	1	1	2	2	2	1	1	2	3	16
User 7	2	1	4	5	5	3	5	2	5	5	37
User 8	2	1	4	5	1	4	3	2	2	5	29
User 9	1	2	2	3	2	2	3	2	2	3	22
User 10	1	1	4	5	2	1	4	1	3	5	27
User 11	1	4	2	5	3	4	4	2	3	5	33
User 12	1	1	1	4	3	4	4	1	5	5	29
User 13	1	3	2	5	2	2	5	2	2	5	29
User 14	2	4	1	4	2	4	4	2	2	4	29
User 15	2	4	2	5	3	3	4	2	4	5	34
User 16	2	2	2	5	3	3	4	1	4	5	31
User 17	1	2	3	4	2	3	4	3	2	4	28
User 18	2	2	3	4	3	3	4	3	2	5	31
User 19	2	2	2	3	2	2	3	2	3	4	25
User 20	1	2	3	4	2	3	4	3	2	5	29
TASK 2	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Score 8	Score 9	Score 10	TOTAL
User 1	3	2	3	5	2	3	4	2	4	5	33
User 2	4	4	3	4	4	3	4	3	3	5	37
User 3	3	4	2	4	3	3	4	3	3	4	33
User 4	2	3	3	5	2	2	3	3	3	5	31
User 5	2	5	3	4	3	3	3	4	3	5	35
User 6	2	2	2	4	2	4	2	2	3	4	27
User 7	2	2	1	5	3	2	1	2	4	5	27
User 8	3	4	3	5	3	2	3	3	3	5	34
User 9	1	2	2	3	2	2	3	2	2	3	22
User 10	2	3	3	5	4	1	4	2	3	5	32
User 11	2	3	3	5	3	4	2	4	4	5	35
User 12	1	1	1	4	3	4	4	1	2	4	25
User 13	5	5	5	5	5	4	4	5	5	5	48
User 14	4	4	4	4	3	4	4	4	4	4	39
User 15	1	2	1	5	2	2	3	1	1	4	22
User 16	3	4	4	5	3	3	4	3	4	5	38
User 17	3	3	2	5	4	3	3	2	3	4	32
User 18	2	2	2	4	2	2	3	4	3	4	28
User 19	3	3	3	4	3	2	4	4	3	5	34
User 20	2	4	3	5	3	4	3	3	4	5	36
TASK 3	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Score 8	Score 9	Score 10	TOTAL
User 1	5	5	5	5	4	5	5	5	5	5	49
User 2	5	4	4	4	3	4	4	3	5	5	41
User 3	3	4	5	5	4	5	5	4	5	5	45
User 4	5	5	4	5	4	4	5	4	5	5	46
User 5	4	5	4	5	4	2	5	5	5	5	44
User 6	5	5	5	5	2	4	5	5	5	5	46
User 7	5	5	4	5	4	2	5	4	5	5	44
User 8	3	4	4	5	3	5	3	4	4	5	40
User 9	1	2	2	3	2	2	3	3	3	4	25
User 10	4	4	5	5	4	5	5	5	5	5	47
User 11	3	4	4	5	3	4	4	4	5	5	41
User 12	4	3	4	4	4	4	5	3	5	4	40
User 13	5	1	4	5	5	4	5	5	5	5	44
User 14	4	4	4	4	3	4	4	4	4	4	39
User 15	3	4	4	5	3	4	4	4	4	5	40
User 16	4	5	4	5	4	5	4	4	5	5	45
User 17	4	3	4	4	3	4	3	5	5	5	40
User 18	4	5	4	5	4	4	3	5	4	5	43
User 19	5	4	5	4	3	4	4	5	5	5	44
User 20	4	4	3	4	4	4	4	5	5	5	42
TASK 4	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Score 7	Score 8	Score 9	Score 10	TOTAL
User 1	5	5	5	5	3	4	5	5	5	5	47
User 2	4	4	5	5	4	4	5	5	4	5	45
User 3	5	5	5	5	5	5	5	5	5	5	50
User 4	5	5	5	5	4	4	4	2	4	5	43
User 5	4	5	4	5	4	5	4	4	4	5	44
User 6	4	4	4	5	2	4	5	3	4	4	39
User 7	4	5	4	5	4	5	5	5	4	5	46
User 8	4	4	4	5	4	4	3	4	5	5	42
User 9	1	2	2	4	2	2	2	2	2	3	22
User 10	5	5	5	5	5	5	5	5	5	5	50
User 11	3	5	3	5	3	4	4	4	5	5	41
User 12	2	3	4	3	4	4	5	2	2	4	33
User 13	5	5	5	5	5	2	5	5	4	5	46
User 14	4	4	4	5	3	4	4	4	4	4	40
User 15	5	5	5	5	5	5	5	5	5	5	50
User 16	4	4	5	5	4	3	4	4	4	5	42
User 17	5	4	4	4	3	5	5	4	5	5	44
User 18	5	5	4	5	4	4	4	5	5	5	46
User 19	3	4	4	4	3	3	4	5	4	5	39
User 20	4	4	5	5	3	4	3	5	4	4	41

Overall Self-reported Form Result

Table 8 summarized the result of the Overall Self-reported score for each task by each subject in Session 2. The highest score reflected the best user satisfaction. The results from the one-way ANOVA (Overall score* Task) and Post Hoc Tests (Appendix O) show that there were significant differences between the new design (Task 4) and the traditional remote control (Task 1) (p= 0.000) and the touchpad (Task 2) (p= 0.000). There were also significant differences between the traditional remote control and the touchpad (p= 0.001). However, there was no significant difference between the new design and the physical keyboard (Task 3) (p= 0.956).

Table 8: Overall Self-reported score of each task by each participant in Session 2

	SESSION 2			
	TASK 1	TASK 2	TASK 3	TASK 4
User S1	1	5	10	7
User S2	3	4	8	8
User S3	3	6	8	10
User S4	2	2	9	10
User S5	1	7	9	8
User S6	1	3	8	5
User S7	1	8	7	9
User S8	5	7	7	8
User S9	3	2	2	4
User S10	2	3	6	8
User S11	2	5	9	10
User S12	6	2	9	4
User S13	2	8	8	6
User S14	1	8	8	4
User S15	4	2	7	10
User S16	5	6	9	8
User S17	2	4	8	6
User S18	3	5	9	7
User S19	4	6	7	8
User S20	2	5	7	9

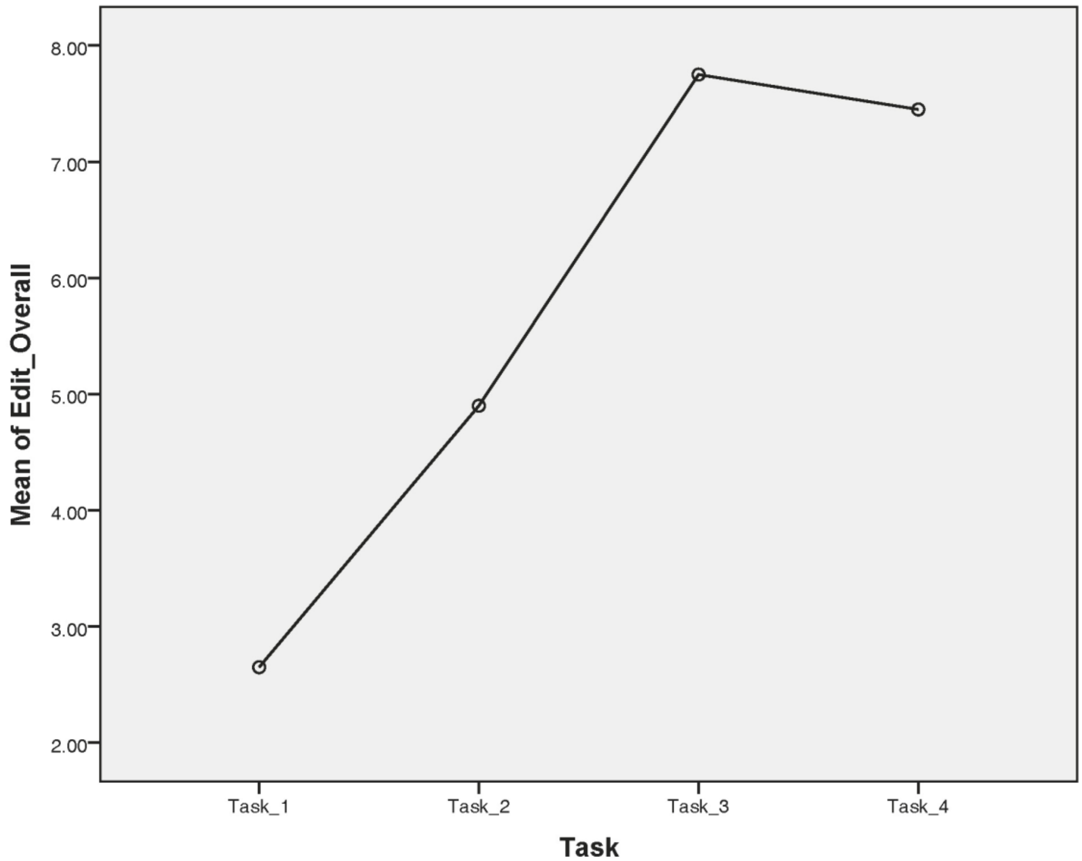


Figure 28: Overall Self-reported Score of each task in Session 2.

CHAPTER 6

DISCUSSION

The hypothesis of this study is that the new design might be more efficient and have higher user satisfaction than the three current methods (the remote control, the touchpad and the physical keyboard) when typing and editing text on the smart TV. The hypothesis was tested by the user testing mentioned in Chapter 4. The results in the Chapter 5 show that the new design was significantly more efficient and had higher satisfaction than the remote control and the touchpad. However, there was no significant difference between the new design and the physical keyboard.

Findings

Finding 1: The new design and the physical keyboard were more efficient as text entry methods for smart TVs than the remote control and the touchpad.

As the results show in Chapter 5, the completion time required to type the sentence using the new design was the lowest value and it was significant different from the remote control and the touchpad. However there was no significant difference between the new design and the physical keyboard. This probably meant that the new design and the physical keyboard were more efficient as text entry methods for smart TVs compared to the remote control and the touchpad.

The data showed that the standard deviation of the completion time using the new design was the lowest which might mean that the new design was more stable and suitable for most users to type text on smart TVs compared to the other three methods.

The result showed that using the remote control and the touchpad to type text on smart TVs was very time consuming compared to the physical keyboard and the new design. This result might be caused by the different typing interactions of the four methods. In the user testing, when using the remote control and the touchpad, most users used one hand to hold the devices and used one finger (thumb) to press the buttons on the remote control or touch the touchpad. While using the physical keyboard and the new method, most users used two hands to hold the devices and used multiple fingers to press buttons on the physical keyboard or on the virtual keyboard of the new app. This might mean multi-finger typing interaction was more efficient than single-finger typing interaction.

Finding 2: The physical keyboard and the new design had higher user satisfaction as text entry methods for smart TVs than the remote control and the touchpad.

The results from RAW-TLX, SUS form and the Overall Self-reported form show that the new method and the physical keyboard had significant higher user satisfaction for typing text on smart TVs than the remote control and the touchpad. However, the results from the Post Hoc Tests show that there was no significant difference between the new design and the physical keyboard on user satisfaction when typing text for smart TVs.

The data showed that the touchpad had lower satisfaction for the typing experience than the remote control even though the touchpad was more efficient for typing text than the remote control. This might mean users preferred to use physical interfaces (physical buttons) to type text on smart TVs compared to virtual interfaces (virtual buttons).

Finding 3: The new design and the physical keyboard were more efficient as text editing methods for smart TVs than the remote control and the touchpad.

Based on the results showed in Chapter 5, the new design took the least time to edit text on smart TVs and it was significant different from the remote control and the touchpad. However there was no significant difference between the new design and the physical keyboard based on the Post Hoc Tests. This probably meant that the new design and the physical keyboard were more efficient as text editing methods for smart TVs than the remote control and the touchpad. The remote control might be less efficient as a text editing method for smart TVs because users spent more time by using the remote control compared to the other methods as the results show in previous chapter.

During the user testing, when users used the remote control to edit text, the biggest challenge for them was that they could not move the cursor in the sentence. Users needed to delete most text when editing the sentence. This might be the main reason that users spent a lot of time on editing using the remote control. The data also showed that the touchpad performed well when editing text. The reason might be that users could easily move the cursor on the screen by using touch gestures. The physical keyboard was also efficient for editing text. In the user testing, when users used the physical keyboard to edit text, they could press and hold the arrow buttons on the keyboard to move the cursor quickly. That might be the main reason that the physical keyboard performed well when editing text.

Finding 4: The new design and the physical keyboard had highest user satisfaction as text editing methods for smart TVs than the remote control and the touchpad.

The results from RAW-TLX, SUS form and Overall Self-reported form show that the new method and the physical keyboard had no significant difference on the user satisfaction for text editing, but these two methods had a significant higher satisfaction than the remote control and the touchpad. The results from Post Hoc Tests also show that the touchpad had significant higher user satisfaction than the remote control, but lower satisfaction than the new design and the physical keyboard.

Significance of the Study

Currently we are in the midst of content revolution of the smart TV[5]. Smart TV provides a universal platform on which people can access to different video contents via one smart TV or set-top box, so that people do not have to use different platforms or devices to watch the videos they like. People can also install many applications on smart TVs which provide new and diverse experiences[5]. However, the interaction between users and smart TVs is not satisfactory, especially bad input experiences such as typing, searching, sending commands. This is one of the key reasons that the progress of the smart TV revolution has slowed down. [5]. As the core of input experience, typing and editing text has a significant effect on user's experience of using smart TVs, so the improvement of text entry and editing experience will speed up the development of the smart TV industry[5].

This study proposed a new input method for smart TVs and provided a method to evaluate the new design compared to three current methods (a remote control, a touchpad, a physical keyboard). All the hypotheses were tested. The new design this study proposed could improve both the efficiency and user satisfaction in typing and editing text on smart TVs. The results of this study can help smart TV companies to improve the user experience of their current smart TV products. In addition, the findings from the user testing can also help companies to improve current input methods and develop new input methods for smart TVs.

Limitations of the Study

While this study produced successful results, it had some limitations. The prototype was developed and tested only on the Android system. However, some subjects said they were not familiar with using Android phones, which might affect their performance on using the new design. In the user testing, a training task was provided to minimize this limitation. However, future study would be necessary to test a prototype developed on the iOS system.

The remote control method used the Amazon Fire TV on-screen keyboard interface which was in alphabetical order. Ideally for consistency of interface, a QWERTY virtual keyboard interface for this method would be better. However, it was very difficult and time consuming to change the keyboard interface on Amazon Fire TV. The original interface was stable and reliable. The training task as mentioned above could minimize this limitation. The Amazon Fire TV keyboard interface had some quick input buttons like ".com". To get more accurate and objective data from remote control methods, subjects were not allowed to use these buttons while they were typing text on the smart TVs. However since these buttons show on the screen, it might be a distraction for users while they were typing. This limitation might have a little effect on subjects' typing time using the remote control.

Suggestions for Current Methods

Based on the results of the user testing and feedback from subjects, this study offered some suggestions for the current methods (the remote control, the touchpad, and the physical keyboard).

The results show that the new design performed better than the remote control and the touchpad. In this study, the new design combined both smartphone touch gestures and virtual keyboards. The touch gestures could help users easily move the cursor in the text field so that users could edit text more effectively. The virtual keyboards on the smartphone allowed users to switch between different keyboards (number, symbol) so that users could type text more effectively. In addition, the interface layout of the new method was easy for users to switch between typing and editing text. The new method also allowed users to type using two hands, which might improve users' typing speed.

The interaction of the remote control was simple and easy to learn. However, it did not provide an efficient way for users to edit text. If this method allowed users to move the cursor in the text filed by using the arrow buttons, it would improve users' editing experience. The interaction of touch gestures could also be incorporated in the remote control method to help improve the editing experience. With this incorporation, users can use touch gestures to move the cursor to edit text and use arrow buttons to type text.

The touchpad was suitable for editing text. However, its typing experience was not satisfactory. If the touchpad function could be combined with other physical buttons or virtual keyboards, it would provide a better experience for text entry on smart TVs.

The physical keyboard performed well when typing and editing text. The only suggestion from users was that the size of the physical keyboard was a little too big to hold in hands. If the physical keyboard could be made smaller, it would provide better experience for smart TV users. To provide a better experience, the physical keyboard can use the layout as the new method, which had a touchpad area on the top and a keyboard on the bottom. With this layout, users can easily hold the device and switch between typing and editing quickly.

CHAPTER 7

CONCLUSION

This study presented a method to evaluate the effects of using smartphone touch gestures and virtual keyboards on the text entry and editing for smart TVs compared to current methods (a remote control, a touchpad, and a physical keyboard). A functional mobile input method for smart TVs was designed and developed for user testing. The critical parameters that were evaluated in the research included: text input efficiency; text input satisfaction; text editing efficiency; text editing satisfaction.

User testing was conducted with 20 participants. The results clearly indicated that it was more efficient to use smartphone touch gestures and virtual keyboards as a text entry and edit method for smart TVs compared to the remote control and the touchpad. It also showed that the new method had similar user satisfaction as the physical keyboard, but it had much higher satisfaction than the remote control and the touchpad. Based on the results of the user testing and feedback from users, the study also offered some suggestions for current input methods to improve their user experience of interacting with smart TVs.

As the core of input experience, typing and editing text has a significant effect on user's experience of using smart TVs, so the improvement of text entry and editing experience will speed up the development of smart TV industry. With the results of this study, it was concluded that the described method of using smartphone touch gestures and virtual keyboards could improve the efficiency of text entry and editing and provide a better user experience than current input methods. The results of this study can also help smart TV companies to improve the user experience of their current smart TV products. In addition, the findings from the user testing can also help companies to improve current input methods and develop new input methods for smart TVs.

Future Study

The next step of this study would involve eliminating one of the main limitations of the study and testing the other functions and features of the new design. Currently, the remote control method tested used the Amazon Fire TV on-screen keyboard interface which was in alphabetical order. It would be better if the interface would be redesigned to a QWERTY virtual keyboard interface for use in the future testing. The core function of the new design, typing and editing text, was tested and evaluated in this study. However, the new design also provides some other important functions. For example, some features allow users to browse and search movies or shows on the phone and play them by selecting them on the phone. It would be better if these other features could be tested and evaluated in the future study.

APPENDIX A

PRE-TEST QUESTIONNAIRE

Introduction:

The purpose of this questionnaire is to gather subjects' experience of using smart TVs and smartphones.
This survey has 3 questions and will take less than 2 minutes to complete.

1. How many years have you been using a smartphone or smartphones (like iPhone or Android Phone)?
Answer: _________________years

2. Have you ever used any of the following smart TV system? Place a check next to all that you have personally used before:

□ Amazon Fire TV
□ Apple TV
□ Google Chromecast
□ Nexus Play
□ Roku
□ Other______________

3. Have you ever used any input device to type text into TV?

a. Yes
b. No

APPENDIX B

TASK ORDER IN EACH SESSION FOR EACH PARTICIPANT

User	Task Order							
	Session 1				Session 2			
	Task 1	Task 2	Task 3	Task 4	Task 1	Task 2	Task 3	Task 4
User 1	1	2	3	4	1	2	3	4
User 2	1	3	4	2	1	3	4	2
User 3	2	1	3	4	2	1	3	4
User 4	3	1	2	4	3	1	2	4
User 5	4	1	2	3	4	1	2	3
User 6	1	2	4	3	1	2	4	3
User 7	2	1	4	3	2	1	4	3
User 8	3	1	4	2	3	1	4	2
User 9	4	1	3	2	4	1	3	2
User 10	1	3	2	4	1	3	2	4
User 11	2	3	1	4	2	3	1	4
User 12	3	2	4	1	3	2	4	1
User 13	4	2	1	3	4	2	1	3
User 14	2	3	4	1	2	3	4	1
User 15	3	2	1	4	3	2	1	4
User 16	4	2	3	1	4	2	3	1
User 17	1	4	2	3	1	4	2	3
User 18	2	4	1	3	2	4	1	3
User 19	3	4	1	2	3	4	1	2
User 20	4	3	2	1	4	3	2	1

APPENDIX C

POST-TEST QUESTIONNAIRE

Type-Remote Control
RAW-TLX Mental Workload Rating Scale Form
Please place an "X" along each scale at the point that best indicates your experience with the input method.

<u>Mental Demand</u>: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

<u>Physical Demand</u>: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

<u>Temporal Demand</u>: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

<u>Performance</u>: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

<u>Effort</u>: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

<u>Frustration</u>: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

System Usability Scale Form
Type-Remote Control

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Type-TouchPad
RAW-TLX Mental Workload Rating Scale Form
Please place an "X" along each scale at the point that best indicates your experience with the input method.

Mental Demand: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

Physical Demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

Temporal Demand: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

Performance: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

Frustration: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

System Usability Scale Form
Type-TouchPad

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Type-Keyboard
RAW-TLX Mental Workload Rating Scale Form
Please place an "X" along each scale at the point that best indicates your experience with the input method.

<u>Mental Demand</u>: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

<u>Physical Demand</u>: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

<u>Temporal Demand</u>: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

<u>Performance</u>: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

<u>Effort</u>: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

<u>Frustration</u>: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

System Usability Scale Form
Type-Keyboard

Strongly disagree — Strongly agree

1. I think that I would like to use this system frequently

1 2 3 4 5

2. I found the system unnecessarily complex

1 2 3 4 5

3. I thought the system was easy to use

1 2 3 4 5

4. I think that I would need the support of a technical person to be able to use this system

1 2 3 4 5

5. I found the various functions in this system were well integrated

1 2 3 4 5

6. I thought there was too much inconsistency in this system

1 2 3 4 5

7. I would imagine that most people would learn to use this system very quickly

1 2 3 4 5

8. I found the system very cumbersome to use

1 2 3 4 5

9. I felt very confident using the system

1 2 3 4 5

10. I needed to learn a lot of things before I could get going with this system

1 2 3 4 5

Type-Mobile App
RAW-TLX Mental Workload Rating Scale Form
Please place an "X" along each scale at the point that best indicates your experience with the input method.

Mental Demand: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

Physical Demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

Temporal Demand: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

Performance: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

Frustration: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

System Usability Scale Form
Type-Mobile App

Statement	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently					
2. I found the system unnecessarily complex					
3. I thought the system was easy to use					
4. I think that I would need the support of a technical person to be able to use this system					
5. I found the various functions in this system were well integrated					
6. I thought there was too much inconsistency in this system					
7. I would imagine that most people would learn to use this system very quickly					
8. I found the system very cumbersome to use					
9. I felt very confident using the system					
10. I needed to learn a lot of things before I could get going with this system					

Edit-Remote Control
RAW-TLX Mental Workload Rating Scale Form
Please place an “X” along each scale at the point that best indicates your experience with the input method.

Mental Demand: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

Physical Demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

Temporal Demand: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

Performance: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

Frustration: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

System Usability Scale Form
Edit-Remote Control

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Edit-TouchPad
RAW-TLX Mental Workload Rating Scale Form

Please place an "X" along each scale at the point that best indicates your experience with the input method.

Mental Demand: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

Physical Demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

Temporal Demand: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

Performance: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

Frustration: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

System Usability Scale Form
Edit-TouchPad

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Edit-Keyboard
RAW-TLX Mental Workload Rating Scale Form
Please place an "X" along each scale at the point that best indicates your experience with the input method.

Mental Demand: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

Physical Demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

Temporal Demand: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

Performance: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

Frustration: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

System Usability Scale Form
Edit-Keyboard

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently					
2. I found the system unnecessarily complex					
3. I thought the system was easy to use					
4. I think that I would need the support of a technical person to be able to use this system					
5. I found the various functions in this system were well integrated					
6. I thought there was too much inconsistency in this system					
7. I would imagine that most people would learn to use this system very quickly					
8. I found the system very cumbersome to use					
9. I felt very confident using the system					
10. I needed to learn a lot of things before I could get going with this system					

Edit-Mobile App
RAW-TLX Mental Workload Rating Scale Form
Please place an “X” along each scale at the point that best indicates your experience with the input method.

<u>Mental Demand</u>: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

<u>Physical Demand</u>: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

<u>Temporal Demand</u>: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

<u>Performance</u>: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

<u>Effort</u>: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

<u>Frustration</u>: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

System Usability Scale Form
Edit-Mobile App

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Session 1 Overall Review Form

Based on text typing experience, please give scores to the 4 input methods. (1 means worst, 10 means best)

Traditional remote controller

1	2	3	4	5	6	7	8	9	10

Touchpad

1	2	3	4	5	6	7	8	9	10

Physical keyboard

1	2	3	4	5	6	7	8	9	10

The mobile app keyboard

1	2	3	4	5	6	7	8	9	10

Any comment or suggestion about the new design:

____

Session 2 Overall Review Form

Based on text editing experience, please give scores to the 4 input methods. (1 means worst, 10 means best)

Traditional remote controller

1	2	3	4	5	6	7	8	9	10

Touchpad

1	2	3	4	5	6	7	8	9	10

Physical keyboard

1	2	3	4	5	6	7	8	9	10

The mobile app keyboard

1	2	3	4	5	6	7	8	9	10

Any comment or suggestion about the new design:

____

APPENDIX D

CONSENT DOCUMENT

Project Title: Comparing and Exploring New Text Entry and Edit Methods for Smart TV
Principal Investigator: Dr. Young Mi Choi
Co-Investigator: Jingtian Li

You are being asked to participate in a research study.

Purpose

The purpose of this research is to evaluate the effects of using smart phone touch gestures and virtual keyboard on the text entry and editing for smart TV.

Exclusion/Inclusion Criteria

A total of 20 people are expected to participate in this study.
Participants in this study must:

- Be aged 18 or over.
- Have a minimum of 1 year of using smart phone experience.
- Have a minimum of 1 year of watching TV experience.

Procedures

If you decide to take part in this study and sign this consent form, you will be asked to take a pre-test survey, participate in an experiment study, and fill a post-test questionnaire.
The experiment will be organized in 2 sessions. The procedures are expected to take approximately 50 minutes but will last no longer than 90 minutes.
Session 1: You will be given a sentence which includes letters, numbers and symbols. The sentence will be shown on a small screen on the side of your seat. You will be asked to use the mobile app we designed, a traditional TV remote control, a Touchpad and a physical TV keyboard to type the given sentence onto the TV screen. You have to correct any typing errors before starting to use next input method. We will measure the time you spend on typing with each input method. After using each method, you will need fill a RAW TLX Form and a System Usability Scale Form.
Session 2: A sentence which includes letters, numbers and symbols will be shown on TV, but there are several typing errors in the sentence. The correct sentence will be shown on a small screen on the side of your seat. You will be asked to use the mobile app we designed, a traditional TV remote control, a Touchpad and a physical TV keyboard to correct the sentence on TV screen. You are not allowed to clear the whole sentence but has to correct certain letters/numbers/symbols in the sentence. The time you spend on correcting the sentence with each input method will be measured. After using each method, you will need fill a RAW TLX Form and a System Usability Scale Form.
After you finish each session, you will be asked to complete a Session Overall Review Form to evaluate these four different input methods.

Risks/Discomforts

The risks involved are no greater than those involved in daily activities like watching TV or using smart phone. To minimize the risks, there will be a 10-minute break between trials. The questionnaire in this study is voluntary and you may skip any questions that you are uncomfortable answering.

Benefits

You may not directly benefit from being in this study. However, your feedback will help to improve people's experience for using smart TV, especially when people want to input online account credentials, input key words to search for favorite TV shows, write comments in forums or app stores, or enter text on smart TV in many other scenarios.

Compensation

You will be given a 10 dollar gift card for participating in this study. The compensation will be provided after completing all of the study procedures.

Confidentiality

We will keep information about you strictly confidential to the extent required by law. Only people associated with this research project will have access to your study records. However, we may be required to release your record if we receive a subpoena or a court order. In addition, to make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB and The Office of Human Research Protections may review study records.

To protest your privacy, no video or audio records will be taken during the study. Your written records will be kept in locked in a file cabinet in a private office. Electronic records will be kept in a pass-coded file on a computer in a private office. Only study staff will have access to the records. We will use a code rather than your name to identify study records. The code will be kept in a separate locked file from the data. Your name and other facts that might point to you will not appear when we present this study or publish its results. Any surveys that might have inadvertently included names or other identifying information will be immediately destroyed. Once the survey data has been input into an electronic database, the original survey forms will be destroyed along with any information linking the electronic data with the original survey.

Costs to You

There will be no costs for participating in this study.

In Case of Injury I Harm

If you are injured as a result of being in this study, please contact the Principal Investigator, Dr. Young-Mi Choi, at telephone (404) 277-2748. Neither the Principal Investigator nor Georgia Institute of Technology has made provision for payment of costs associated with any injury resulting from participation in this study.

Participant Rights

- Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
- You have the right to change your mind and leave the study at any time without giving any reason, and without penalty.
- If you decide not to finish the study, you have the right to withdraw any data collected about you. Your paperwork will be shredded.
- Any new information that may make you change your mind about being in this study will be given to you.

- You will be given a copy of this consent form to keep.
- You do not waive any of your legal rights by signing this consent form.

<u>Questions about the Study</u>
If you have any questions about the study, you may contact Dr. Young-Mi Choi, at telephone (404) 277-2748 or christina.choi@gatech.edu.

<u>Questions about Your Rights as a Research Participant</u>
If you have any questions about your rights as a research subject, you may contact: Ms. Melanie Clark, Georgia Institute of Technology, Office of Research Compliance at (404) 894-6942 or Ms. Kelly Winn, Georgia Institute of Technology Office of Research Compliance, at (404) 385-2175.

If you sign below, it means that you have read (or have had read to you) the information given in this consent form, and you would like to be a volunteer in this study.

____
Participant Name (printed)

____ ____________
Participant Signature Date

____ ____________
Signature of Person Obtaining Consent Date

APPENDIX E

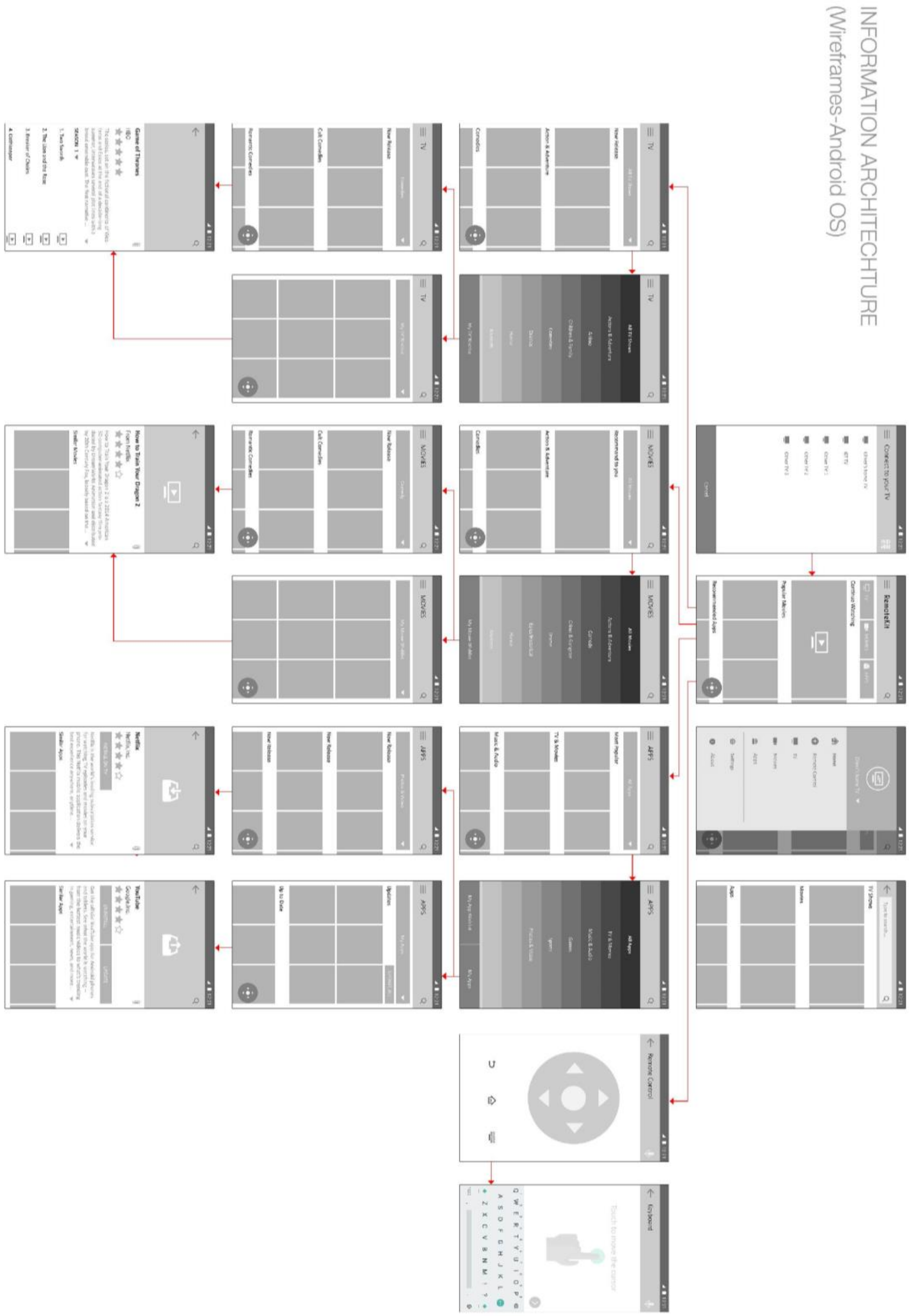
RECRUITMENT SCRIPT

Hello, my name is Jingtian Li and I'm a graduate student from Georgia Institute of Technology. We are looking for participants to be in a research study. The purpose of this research is to evaluate the effects of using smart phone touch gestures and virtual keyboard on the text entry and editing for smart TV. In this study, you will be asked to enter and edit text on a smart TV using four different methods. Before and after the test, you will be asked to fill a pre-test survey and a post-test questionnaire. We are reaching out to you because you are over 18 years old, have more than 1 year using smart phone experience and more than 1 year watching TV experience, which meet the inclusion criteria of the study.

The experiment will be organized in 2 sessions. The procedures are expected to take approximately 50 minutes but will last no longer than 90 minutes. Your participation will be appreciated and a $10 gift card will be provided as compensation. The information obtained from this study will be used to propose an approach that provides a more effective method of text entry and editing on smart TV.

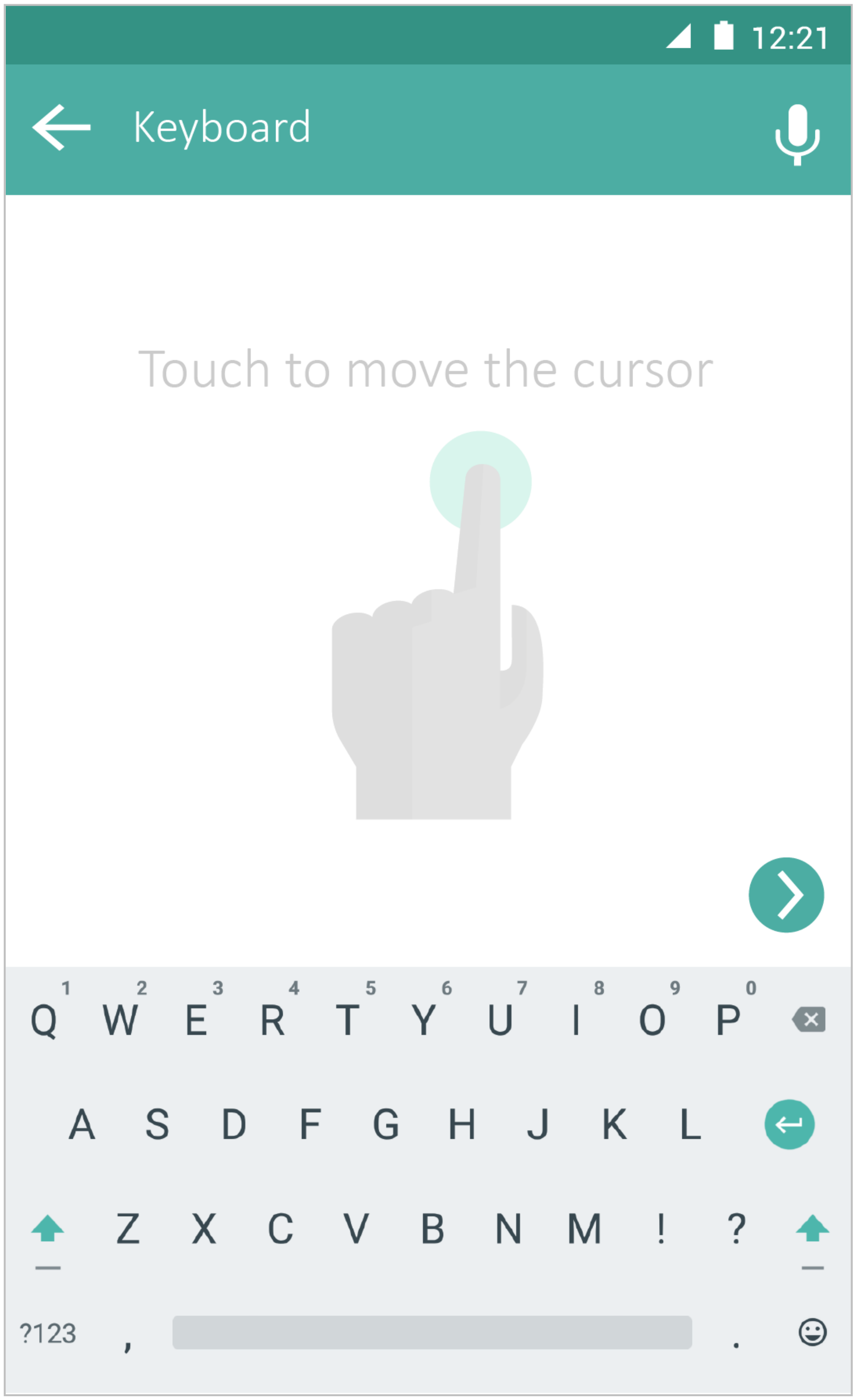
APPENDIX F

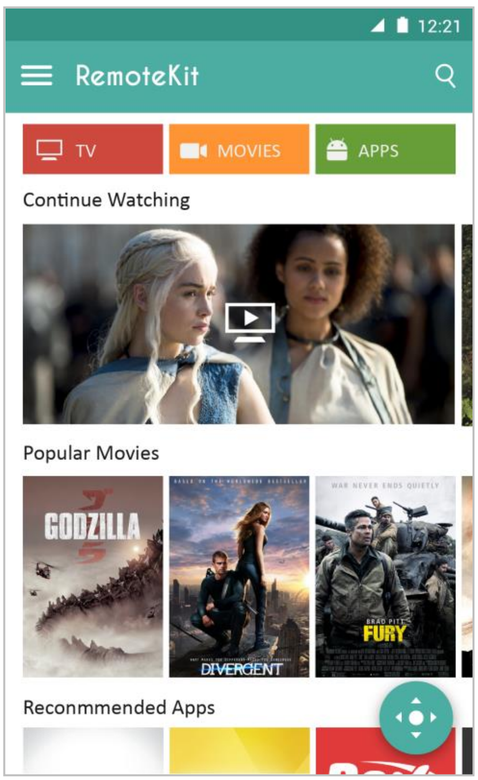
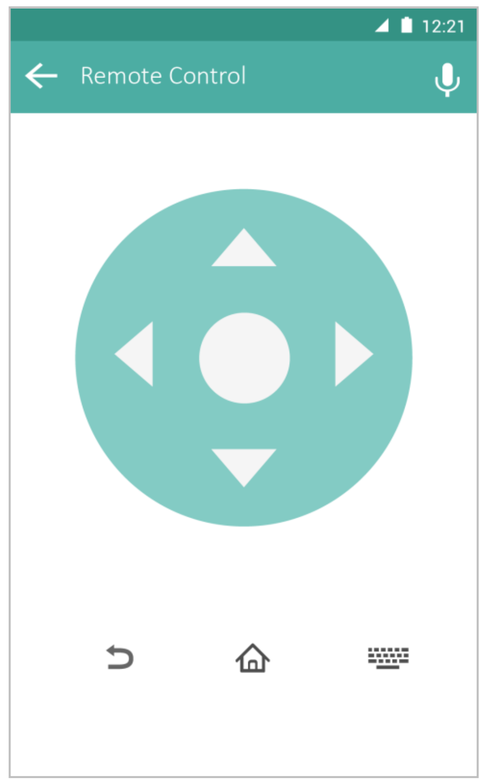
WIREFRAME OF THE NEW DESIGN

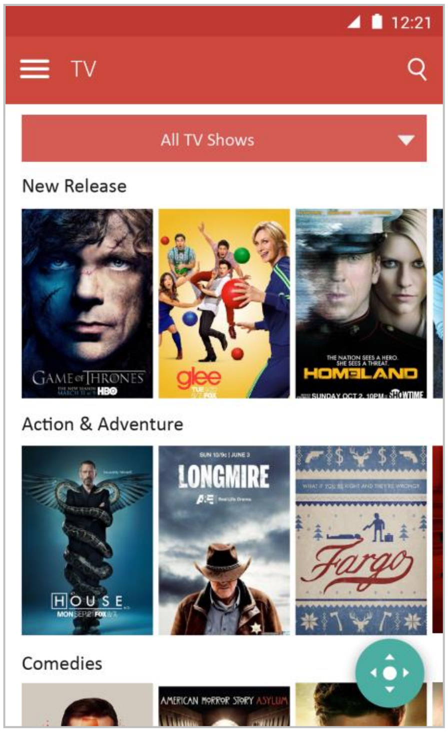


APPENDIX G

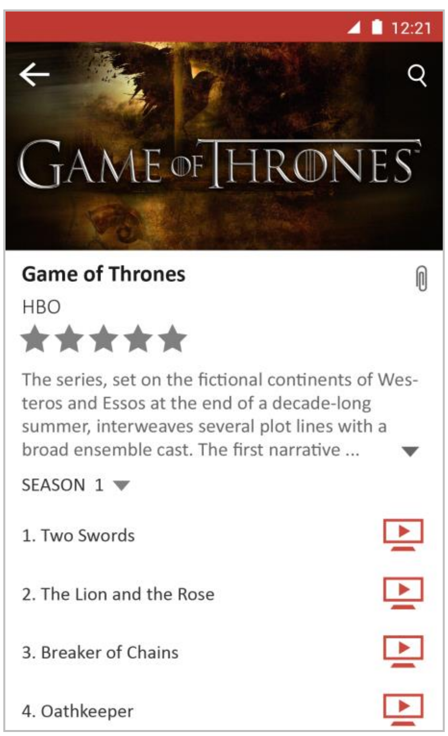
USER INTERFACE OF THE NEW DESIGN

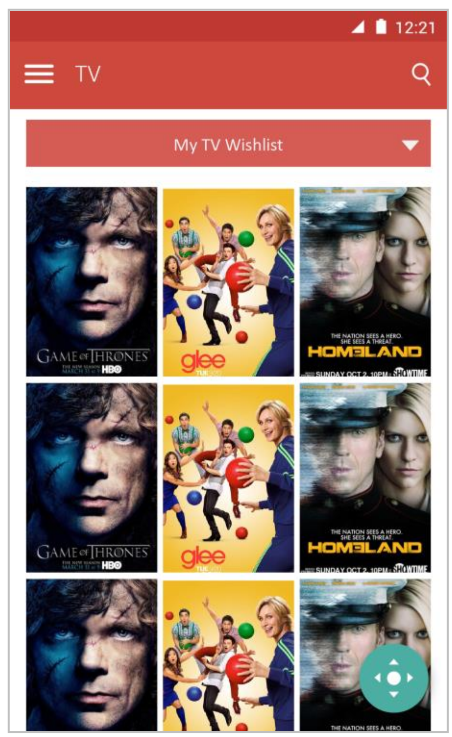


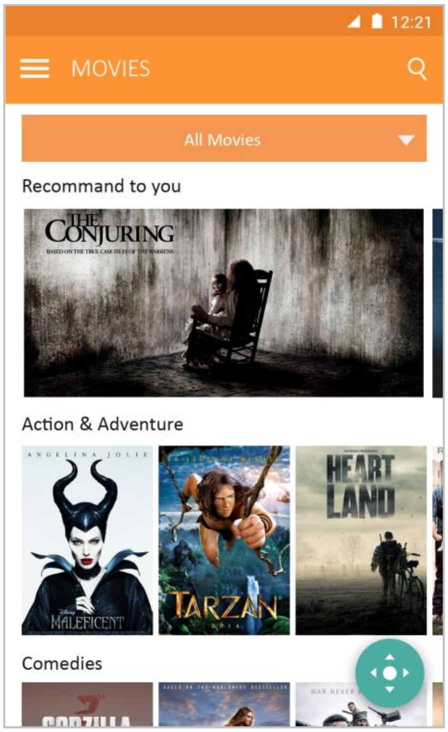

12:21
RemoteKit
TV
MOVIES
APPS
Continue Watching
Popular Movies
GODZILLA
DIVERGENT
FURY
Reconmmended Apps

12:21
Remote Control


12:21
TV
All TV Shows
New Release
Action & Adventure
Comedies

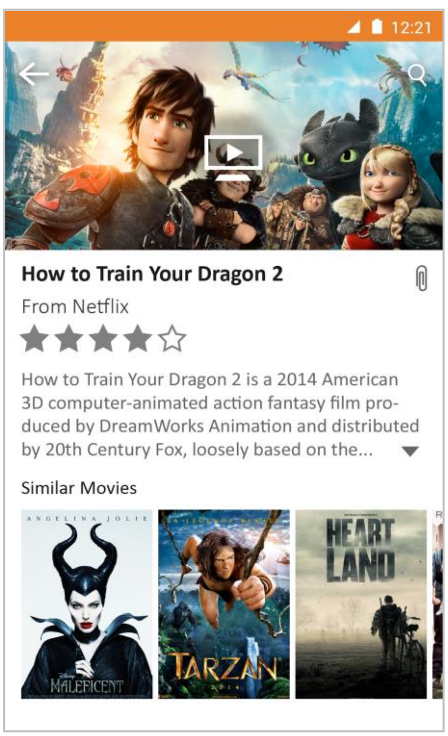

12:21
TV
All TV Shows
Actions & Adventure
Anime
Children & Family
Comedies
Dramas
Horror
Musicals
My TV Wishlist

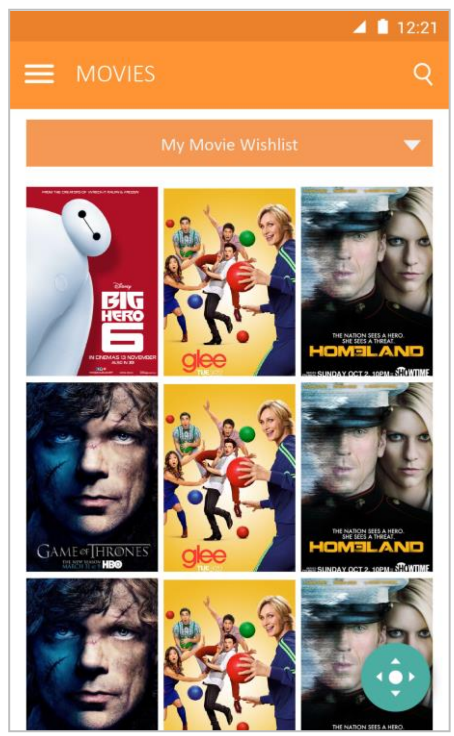

12:21
GAME OF THRONES
Game of Thrones
HBO
The series, set on the fictional continents of Wes-
teros and Essos at the end of a decade-long
summer, interweaves several plot lines with a
broad ensemble cast. The first narrative ...
SEASON 1
1. Two Swords
2. The Lion and the Rose
3. Breaker of Chains
4. Oathkeeper

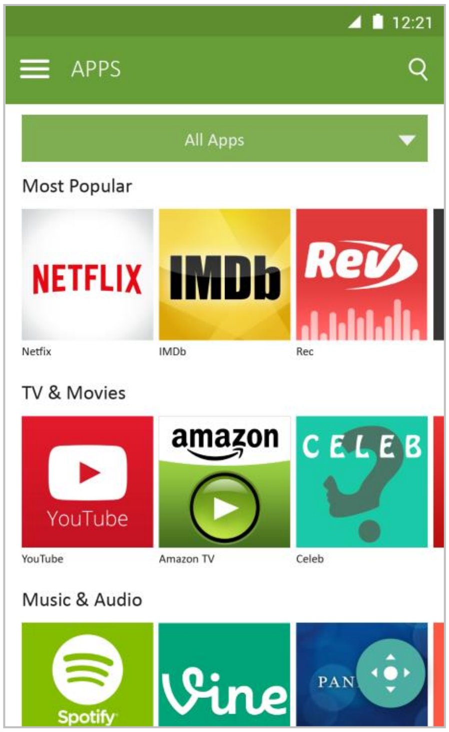

12:21
TV
My TV Wishlist

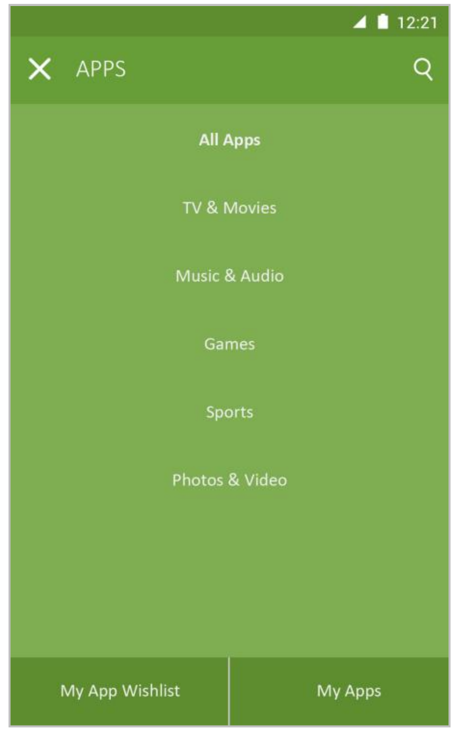

12:21
MOVIES
All Movies
Recommand to you
THE CONJURING
Action & Adventure
MALEFICENT
TARZAN
HEART LAND
Comedies

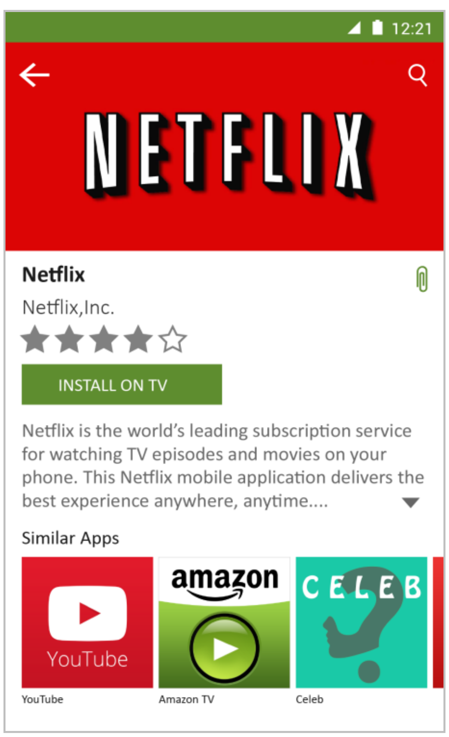

12:21
MOVIES
All Movies
Actions & Adventure
Comedy
Crime & Gangster
Drame
Epics/Historical
Horror
Musicals
My Movie Wishlist

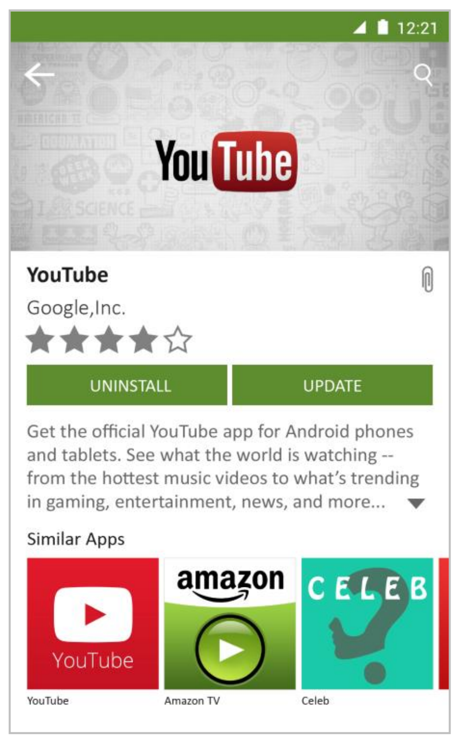

12:21
How to Train Your Dragon 2
From Netflix
How to Train Your Dragon 2 is a 2014 American 3D computer-animated action fantasy film produced by DreamWorks Animation and distributed by 20th Century Fox, loosely based on the...
Similar Movies
MALEFICENT
TARZAN
HEART LAND


12:21
MOVIES
My Movie Wishlist
BIG HERO 6
glee
HOMELAND
GAME of THRONES
glee
HOMELAND


12:21
APPS
All Apps
Most Popular
NETFLIX
IMDb
Netfix
IMDb
Rec
TV & Movies
YouTube
amazon
CELEB
YouTube
Amazon TV
Celeb
Music & Audio
Spotify
Vine
PAN


12:21
APPS
All Apps
TV & Movies
Music & Audio
Games
Sports
Photos & Video
My App Wishlist
My Apps


12:21
NETFLIX
Netflix
Netflix,Inc.
INSTALL ON TV
Netflix is the world's leading subscription service for watching TV episodes and movies on your phone. This Netflix mobile application delivers the best experience anywhere, anytime....
Similar Apps
YouTube
amazon
CELEB
YouTube
Amazon TV
Celeb


12:21
You Tube
YouTube
Google,Inc.
UNINSTALL
UPDATE
Get the official YouTube app for Android phones and tablets. See what the world is watching -- from the hottest music videos to what's trending in gaming, entertainment, news, and more...
Similar Apps
YouTube
amazon
CELEB
YouTube
Amazon TV
Celeb

APPENDIX H

ANOVA TEST ON COMPLETION TIME IN SESSION 1

Oneway

Descriptives

Type_Time

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Task_1	20	329.2500	48.01302	10.73604	306.7792	351.7208
Task_2	20	320.8000	75.65197	16.91630	285.3938	356.2062
Task_3	20	108.7500	20.57304	4.60027	99.1215	118.3785
Task_4	20	89.7500	14.77863	3.30460	82.8334	96.6666
Total	80	212.1375	122.65747	13.71352	184.8414	239.4336

ANOVA

Type_Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1023811.038	3	341270.346	157.446	.000
Within Groups	164732.450	76	2167.532		
Total	1188543.488	79			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Type_Time

Tukey HSD

(I) Task	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Task_1	Task_2	8.45000	14.72254	.940	-30.2231	47.1231
	Task_3	220.50000*	14.72254	.000	181.8269	259.1731
	Task_4	239.50000*	14.72254	.000	200.8269	278.1731
Task_2	Task_1	-8.45000	14.72254	.940	-47.1231	30.2231
	Task_3	212.05000*	14.72254	.000	173.3769	250.7231
	Task_4	231.05000*	14.72254	.000	192.3769	269.7231
Task_3	Task_1	-220.50000*	14.72254	.000	-259.1731	-181.8269
	Task_2	-212.05000*	14.72254	.000	-250.7231	-173.3769
	Task_4	19.00000	14.72254	.572	-19.6731	57.6731
Task_4	Task_1	-239.50000*	14.72254	.000	-278.1731	-200.8269
	Task_2	-231.05000*	14.72254	.000	-269.7231	-192.3769
	Task_3	-19.00000	14.72254	.572	-57.6731	19.6731

*. The mean difference is significant at the 0.05 level.

APPENDIX I

ANOVA TEST ON RAW TLX FORM IN SESSION 1

Oneway

Descriptives

Type_TLX

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Task_1	20	54.6500	16.58558	3.70865	46.8877	62.4123
Task_2	20	70.3500	25.45228	5.69130	58.4380	82.2620
Task_3	20	28.7500	11.63423	2.60149	23.3050	34.1950
Task_4	20	27.0500	17.44910	3.90174	18.8836	35.2164
Total	80	45.2000	25.73694	2.87748	39.4725	50.9275

ANOVA

Type_TLX

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26437.000	3	8812.333	25.867	.000
Within Groups	25891.800	76	340.682		
Total	52328.800	79			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Type_TLX

Tukey HSD

(I) Task	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Task_1	Task_2	-15.70000*	5.83679	.043	-31.0321	-.3679
	Task_3	25.90000*	5.83679	.000	10.5679	41.2321
	Task_4	27.60000*	5.83679	.000	12.2679	42.9321
Task_2	Task_1	15.70000*	5.83679	.043	.3679	31.0321
	Task_3	41.60000*	5.83679	.000	26.2679	56.9321
	Task_4	43.30000*	5.83679	.000	27.9679	58.6321
Task_3	Task_1	-25.90000*	5.83679	.000	-41.2321	-10.5679
	Task_2	-41.60000*	5.83679	.000	-56.9321	-26.2679
	Task_4	1.70000	5.83679	.991	-13.6321	17.0321
Task_4	Task_1	-27.60000*	5.83679	.000	-42.9321	-12.2679
	Task_2	-43.30000*	5.83679	.000	-58.6321	-27.9679
	Task_3	-1.70000	5.83679	.991	-17.0321	13.6321

*. The mean difference is significant at the 0.05 level.

APPENDIX J

ANOVA TEST ON SUS FORM IN SESSION 1

Oneway

Descriptives

Type_SUS

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound
Task_1	20	33.2500	6.06001	1.35506	30.4138	36.0862
Task_2	20	29.5000	7.27288	1.62626	26.0962	32.9038
Task_3	20	42.1500	5.26433	1.17714	39.6862	44.6138
Task_4	20	41.0500	7.68782	1.71905	37.4520	44.6480
Total	80	36.4875	8.41637	.94098	34.6145	38.3605

ANOVA

Type_SUS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2243.737	3	747.912	16.956	.000
Within Groups	3352.250	76	44.109		
Total	5595.987	79			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Type_SUS

Tukey HSD

(I) Task	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Task_1	Task_2	3.75000	2.10020	.288	-1.7668	9.2668
	Task_3	-8.90000*	2.10020	.000	-14.4168	-3.3832
	Task_4	-7.80000*	2.10020	.002	-13.3168	-2.2832
Task_2	Task_1	-3.75000	2.10020	.288	-9.2668	1.7668
	Task_3	-12.65000*	2.10020	.000	-18.1668	-7.1332
	Task_4	-11.55000*	2.10020	.000	-17.0668	-6.0332
Task_3	Task_1	8.90000*	2.10020	.000	3.3832	14.4168
	Task_2	12.65000*	2.10020	.000	7.1332	18.1668
	Task_4	1.10000	2.10020	.953	-4.4168	6.6168
Task_4	Task_1	7.80000*	2.10020	.002	2.2832	13.3168
	Task_2	11.55000*	2.10020	.000	6.0332	17.0668
	Task_3	-1.10000	2.10020	.953	-6.6168	4.4168

*. The mean difference is significant at the 0.05 level.

APPENDIX K

ANOVA TEST ON OVERALL FORM IN SESSION 1

Oneway

Descriptives

Type_Overall

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Task_1	20	4.1500	2.25424	.50406	3.0950	5.2050
Task_2	20	3.7500	2.61323	.58433	2.5270	4.9730
Task_3	20	7.4500	1.57196	.35150	6.7143	8.1857
Task_4	20	7.2000	2.16673	.48450	6.1859	8.2141
Total	80	5.6375	2.73858	.30618	5.0281	6.2469

ANOVA

Type_Overall

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	230.038	3	76.679	16.078	.000
Within Groups	362.450	76	4.769		
Total	592.488	79			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Type_Overall

Tukey HSD

(I) Task	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Task_1	Task_2	.40000	.69059	.938	-1.4140	2.2140
	Task_3	-3.30000*	.69059	.000	-5.1140	-1.4860
	Task_4	-3.05000*	.69059	.000	-4.8640	-1.2360
Task_2	Task_1	-.40000	.69059	.938	-2.2140	1.4140
	Task_3	-3.70000*	.69059	.000	-5.5140	-1.8860
	Task_4	-3.45000*	.69059	.000	-5.2640	-1.6360
Task_3	Task_1	3.30000*	.69059	.000	1.4860	5.1140
	Task_2	3.70000*	.69059	.000	1.8860	5.5140
	Task_4	.25000	.69059	.984	-1.5640	2.0640
Task_4	Task_1	3.05000*	.69059	.000	1.2360	4.8640
	Task_2	3.45000*	.69059	.000	1.6360	5.2640
	Task_3	-.25000	.69059	.984	-2.0640	1.5640

*. The mean difference is significant at the 0.05 level.

APPENDIX L

ANOVA TEST ON COMPLETION TIME IN SESSION 2

Oneway

Descriptives

Edit_Time

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Task_1	20	291.5500	42.36120	9.47225	271.7243	311.3757
Task_2	20	89.0000	19.50978	4.36252	79.8691	98.1309
Task_3	20	45.9000	9.40828	2.10376	41.4968	50.3032
Task_4	20	43.2500	13.37269	2.99023	36.9914	49.5086
Total	80	117.4250	105.62122	11.80881	93.9201	140.9299

ANOVA

Edit_Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	834905.050	3	278301.683	455.775	.000
Within Groups	46406.500	76	610.612		
Total	881311.550	79			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Edit_Time

Tukey HSD

(I) Task	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Task_1	Task_2	202.55000*	7.81417	.000	182.0238	223.0762
	Task_3	245.65000*	7.81417	.000	225.1238	266.1762
	Task_4	248.30000*	7.81417	.000	227.7738	268.8262
Task_2	Task_1	-202.55000*	7.81417	.000	-223.0762	-182.0238
	Task_3	43.10000*	7.81417	.000	22.5738	63.6262
	Task_4	45.75000*	7.81417	.000	25.2238	66.2762
Task_3	Task_1	-245.65000*	7.81417	.000	-266.1762	-225.1238
	Task_2	-43.10000*	7.81417	.000	-63.6262	-22.5738
	Task_4	2.65000	7.81417	.986	-17.8762	23.1762
Task_4	Task_1	-248.30000*	7.81417	.000	-268.8262	-227.7738
	Task_2	-45.75000*	7.81417	.000	-66.2762	-25.2238
	Task_3	-2.65000	7.81417	.986	-23.1762	17.8762

*. The mean difference is significant at the 0.05 level.

APPENDIX M

ANOVA TEST ON RAW TLX IN SESSION 2

Oneway

Descriptives

Edit_TLX

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound
Task_1	20	69.8000	21.33344	4.77030	59.8156	79.7844
Task_2	20	46.3000	22.36327	5.00058	35.8337	56.7663
Task_3	20	24.6000	15.89240	3.55365	17.1621	32.0379
Task_4	20	24.0000	16.34175	3.65413	16.3518	31.6482
Total	80	41.1750	26.70266	2.98545	35.2326	47.1174

ANOVA

Edit_TLX

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	28307.350	3	9435.783	25.591	.000
Within Groups	28022.200	76	368.713		
Total	56329.550	79			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Edit_TLX

Tukey HSD

(I) Task	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Task_1	Task_2	23.50000*	6.07218	.001	7.5496	39.4504
	Task_3	45.20000*	6.07218	.000	29.2496	61.1504
	Task_4	45.80000*	6.07218	.000	29.8496	61.7504
Task_2	Task_1	-23.50000*	6.07218	.001	-39.4504	-7.5496
	Task_3	21.70000*	6.07218	.003	5.7496	37.6504
	Task_4	22.30000*	6.07218	.002	6.3496	38.2504
Task_3	Task_1	-45.20000*	6.07218	.000	-61.1504	-29.2496
	Task_2	-21.70000*	6.07218	.003	-37.6504	-5.7496
	Task_4	.60000	6.07218	1.000	-15.3504	16.5504
Task_4	Task_1	-45.80000*	6.07218	.000	-61.7504	-29.8496
	Task_2	-22.30000*	6.07218	.002	-38.2504	-6.3496
	Task_3	-.60000	6.07218	1.000	-16.5504	15.3504

*. The mean difference is significant at the 0.05 level.

APPENDIX N

ANOVA TEST ON SUS FORM IN SESSION 2

Oneway

Descriptives

Edit_SUS

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Task_1	20	28.1500	4.64843	1.03942	25.9745	30.3255
Task_2	20	32.4000	6.16783	1.37917	29.5134	35.2866
Task_3	20	42.2500	4.89764	1.09514	39.9578	44.5422
Task_4	20	42.5000	6.41954	1.43545	39.4956	45.5044
Total	80	36.3250	8.32987	.93131	34.4713	38.1787

ANOVA

Edit_SUS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3109.450	3	1036.483	33.208	.000
Within Groups	2372.100	76	31.212		
Total	5481.550	79			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Edit_SUS

Tukey HSD

(I) Task	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Task_1	Task_2	-4.25000	1.76669	.085	-8.8907	.3907
	Task_3	-14.10000*	1.76669	.000	-18.7407	-9.4593
	Task_4	-14.35000*	1.76669	.000	-18.9907	-9.7093
Task_2	Task_1	4.25000	1.76669	.085	-.3907	8.8907
	Task_3	-9.85000*	1.76669	.000	-14.4907	-5.2093
	Task_4	-10.10000*	1.76669	.000	-14.7407	-5.4593
Task_3	Task_1	14.10000*	1.76669	.000	9.4593	18.7407
	Task_2	9.85000*	1.76669	.000	5.2093	14.4907
	Task_4	-.25000	1.76669	.999	-4.8907	4.3907
Task_4	Task_1	14.35000*	1.76669	.000	9.7093	18.9907
	Task_2	10.10000*	1.76669	.000	5.4593	14.7407
	Task_3	.25000	1.76669	.999	-4.3907	4.8907

*. The mean difference is significant at the 0.05 level.

APPENDIX O

ANOVA TEST ON OVERALL FORM IN SESSION 2

Oneway

Descriptives

Edit_Overall

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Task_1	20	2.6500	1.49649	.33462	1.9496	3.3504
Task_2	20	4.9000	2.10013	.46960	3.9171	5.8829
Task_3	20	7.7500	1.68195	.37609	6.9628	8.5372
Task_4	20	7.4500	2.03845	.45581	6.4960	8.4040
Total	80	5.6875	2.76320	.30894	5.0726	6.3024

ANOVA

Edit_Overall

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	344.138	3	114.712	33.654	.000
Within Groups	259.050	76	3.409		
Total	603.188	79			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Edit_Overall

Tukey HSD

(I) Task	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Task_1	Task_2	-2.25000*	.58383	.001	-3.7836	-.7164
	Task_3	-5.10000*	.58383	.000	-6.6336	-3.5664
	Task_4	-4.80000*	.58383	.000	-6.3336	-3.2664
Task_2	Task_1	2.25000*	.58383	.001	.7164	3.7836
	Task_3	-2.85000*	.58383	.000	-4.3836	-1.3164
	Task_4	-2.55000*	.58383	.000	-4.0836	-1.0164
Task_3	Task_1	5.10000*	.58383	.000	3.5664	6.6336
	Task_2	2.85000*	.58383	.000	1.3164	4.3836
	Task_4	.30000	.58383	.956	-1.2336	1.8336
Task_4	Task_1	4.80000*	.58383	.000	3.2664	6.3336
	Task_2	2.55000*	.58383	.000	1.0164	4.0836
	Task_3	-.30000	.58383	.956	-1.8336	1.2336

*. The mean difference is significant at the 0.05 level.

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